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ABSTRACT

The diversity of the educational system of the United States that engenders a wealth of innovative ideas and varied practices also makes it an extremely complex system to confront and understand as a whole. This survey was undertaken to develop current baseline data on all secondary school teachers of physics in the United States, including those teaching in parochial and non-religiously affiliated private schools. The study was designed to elicit information from occasional teachers of physics as well as those teachers who specialize in the subject. The first three sections of this report include background information for the study including recent studies and methodology. Sections 4 through 8 focus on physics teachers. Information in these sections includes a profile of the sample, salaries, job satisfaction, experience, career plans, and teacher attitudes. Section 9 examines the structure of physics curricula in the schools. Public and private physics education are compared in section 10. (CW)

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Findings from the

1986–87 NATIONWIDE SURVEY OF SECONDARY SCHOOL TEACHERS ON PHYSICS

by Michael Neuschatz and Marnie Covalt

E 050 232

PHYSICS IN THE HIGH SCHOOLS

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Physics in the High Schools

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by Michael Neuschatz and Maude Covalt

American Institute of Physics
June 1, 1988

The survey findings presented in this report are the fruit of a long-term collaborative effort between the American Institute of Physics and the American Association of Physics Teachers, with important contributions from other AIP Member Societies as well. Special thanks for preparing the groundwork and aiding in the development of the survey instrument are due to John Layman, Jack Wilson, W. C. Kelly, and Katherine Mays. Additional thanks for help and suggestions along the way are due to members of AAPT's High School Committee and to participants in AIP's High School Science Workshop, held in February 1988.

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I. INTRODUCTION

It has often been remarked that the decentralized character of the educational system in the United States constitutes one of its greatest weaknesses as well as one of its greatest strengths. While such statements have usually referred to difficulties in insuring fair and consistent administration among the rich variety of its component parts, the same observation also holds for efforts to describe the education system and analyze its inner workings. The very diversity that engenders a wealth of innovative ideas and varied practices also makes it an extremely complex system to confront and understand (much less plan for) as a whole. The absence of a centralized administrative structure removes the natural locus for a compendium of system-wide data, and makes consistency of data definition and standardization of data collection much more difficult to ensure. Against this background, the care and expense required to assemble reliable information has severely limited the scope and detail that nationwide quantitative studies can practically encompass. Wide-ranging and in-depth studies of "specialty" areas with relatively small enrollments like physics are very rare.

The American Institute of Physics' 1986–87 Nationwide Survey of Secondary School Teachers of Physics was undertaken on behalf of its member societies and especially the American Association of Physics Teachers, to develop current baseline data on all secondary school teachers of physics in the United States, including those teaching in parochial and non-religiously-affiliated private schools. The study was designed to elicit information from occasional teachers of physics as well as those teachers who specialize in the subject. The survey instrument was developed as a collaborative effort of the AAPT and the AIP, and was pretested on a sample of several hundred AAPT members.

In terms of content, the survey focuses on the individual background characteristics of teachers, their conditions of employment, their professional development interests and activities, and their approaches to and experiences in physics teaching. Information has also been obtained on the structure of physics programs in secondary schools across the nation, including variations in the availability of physics classes and the breadth of courses offered across widely differing types of schools.

The view that a well-trained and scientifically literate population is needed to ensure the future economic "competitiveness" and socio-political health of our society has gained wide currency in recent years. As one writer put it recently in an article appearing in a major newspaper, "Citizens are routinely finding themselves facing decisions that require scientific judgments . . .But there is uneasiness that many Americans are ill equipped by their science educations to make such decisions intelligently."[1] Another commentator, taking note of the recently renewed emphasis in the National Science Foundation on pre-college science education, observed that "In the post-Sputnik push, the focus was on students heading for careers in science, engineering, or mathematics. This time, . . .a broader aim is to increase the scientific literacy of the workforce."[2] (A fuller

exposition of this viewpoint can be found in numerous other places, for example, Holton (1986) and Kearns and Doyle (1987). However, there are still strong voices—for instance, Shamos (1988)—arguing for the opposing point of view).

Partly in response to this renewed emphasis on science education and science literacy, this study was undertaken with the expectation that the findings would prove to be valuable in tracking progress towards these broad objectives at a time when physics teachers are becoming an ever-scarcer national resource. It is hoped that this study and its follow-ups will aid in monitoring the impact of current and future changes in high school graduation requirements and teacher certification on the levels of supply and demand for high school physics teachers, as well as on the level and scope of the material being presented to students in different types of physics courses. Most importantly, we hope that this study will prove helpful to the almost twenty thousand teachers of physics scattered throughout this nation's high schools. It is they who made this research effort possible, and gave it substance. If we can, in return, help to provide them with a better sense of the "big picture," and offer them information which can help guide their ongoing efforts to extend and upgrade the level of physics education in the high schools, we will consider this to have been a job well done. For, in the last analysis, it is the teachers, individually and through professional organizations such as the AAPT and the National Science Teachers Association, who will decide how the information brought to light in this study might best be used to further physics instruction in the secondary schools.

The first three sections of this report contain background material for the study. Section II takes a brief look at some of the recent studies that have gathered data on high school physics teaching, data against which we can make rough comparisons with our own findings. Section III provides a short outline of the methodology employed in carrying out this study, with a more detailed presentations saved for Appendix A. Attention then shifts to a discussion of the findings themselves, as we present, in Section IV, an overview of the contours of physics instruction at the secondary school level across the United States, with a special focus on public schools.

The following four sections shift the spotlight to the people who actually teach physics in this nation's high schools. Section V offers a summary profile of the teachers who completed our survey, while Section VI looks more closely at teachers' salary levels, job satisfaction and career plans. Section VII explores the subjective side of the physics teaching experience—the objectives pursued, the problems encountered, and the attitudes held concerning several rather controversial proposals that have been aired recently. Section VIII rounds out the picture presented of teachers by comparing the attributes of men and women in our sample, in addition to comparisons of newer versus more senior teachers and of those specializing in physics teaching as against those concentrating on other fields who were brought in to teach physics.

In Section IX, the focus turns to the structure of the schools' physics curricula, comparing the different types and levels of courses offered, and honing in on the characteristics of the regular first-year course, overwhelmingly the most widely taught. Section X returns to physics education outside the public school system, highlighting the similarities and differences in approach between public schools and parochial and private academies. Finally, Section XI offers some concluding remarks on the state of physics in the high schools, stepping back to consider the "big picture," taking a look at the standing of the United States in some very preliminary comparative findings derived from a recent international study, and mapping out some issues that appear ripe for further analysis in future studies.

II. EARLIER RESEARCH INTO SECONDARY SCHOOL PHYSICS TEACHING

Given the fractionalized character of the U.S. educational system and the consequent problems and expense in studying it, it is hardly surprising that much of the previous research focusing on high school physics has employed anecdotal evidence or qualitative surveys for curriculum reviews or explorations of teachers' experiences and pedagogical techniques. Of those few studies that have aimed at statistical representativeness, most have relied on data gathered by the U.S. Department of Education (formerly Health, Education and Welfare), the National Science Foundation, and other government agencies. Unfortunately, government surveys that tried to cover all aspects of public education rarely devoted much space to low-enrollment specialties such as physics. Studies relying on these governmental data bases were thus often forced to trade depth for breadth. Still, based on government data collected over many years, baseline historical information on secondary school physics instruction was compiled and included in a broader statistical handbook on the profession as a whole published in 1964 by the AIP's Department of Manpower Studies, data which will permit some rough historical comparisons at various points in this report.

More recent data collected by government agencies has shown greater promise. Especially worthy of note is a massive longitudinal data base, known as High School and Beyond, that is currently being assembled from repeated surveys of high school students (including post-graduation follow-ups) by the Department of Education's National Center for Education Statistics. While that data set encompasses all subject areas, its scope permits some detail even at the subject level of analysis. The AIP's Education and Employment Statistics Division is currently working on an analysis of the patterns of student enrollment in high school science and mathematics courses. The study employs data gathered in the High School and Beyond 1980 panel of surveys of high school seniors and closely complements the analysis based on teacher responses presented here.

There are a number of other studies relying on government data, mostly covering all the natural sciences (and often mathematics as well), that have included sections on high school physics. But these efforts have by and large been limited

by the coverage and quality problems typically encountered in national data sets of this type. Many researchers have been dissatisfied with the commensurability of the data gathered at the federal level from state and local sources. (Others have bemoaned the almost total lack of statistically-reliable data on private and parochial schools.) Several have been impelled by their dissatisfaction with government compilations to conduct separate surveys of their own. Among the more recent of these research efforts, we look to the 1977 NSF-supported National Survey of Science and Mathematics Education conducted by Weiss, and its 1985 follow-up, for comparisons with our own findings. Still Weiss's school surveys also focused on science education as a whole, and asked only the broadest questions about physics as a separate subject area.

Another important survey including questions on physics teaching was conducted by Bill Aldridge of the National Science Teachers' Association in 1985–86. While a number of methodological issues (including problems with the response rate and with the completeness of the original list from which the sample was chosen) cloud the question of generalizability of the findings, the NSTA questionnaire included several items that closely paralleled questions employed in our own survey, and approached the definition of teacher of physics in a way that makes comparison with our findings relatively easy. Thus, the NSTA results, along with the Weiss studies and AIP's own analysis of the High School and Beyond data base, constitute the primary background against which the figures reported below will be compared where appropriate. In addition, a number of studies of physics teachers and physics curricula have been carried out at the state level—notably, New Jersey, Wisconsin and Rhode Island, in recent years. The results of these efforts can also be used for comparison where feasible, keeping in mind the small sample sizes and other problems of commensurability. By these means we hope to be able to present not merely a cross-sectional view of the current state of physics education in the U.S., but also a sense of its history and its future directions, as well as a hint of the results that different approaches might yield.

Cross-national comparisons would also have been of immense value in trying to assess the relative value of different approaches to physics teaching. However, differences in educational structures make such comparisons very difficult. One recent study that attempted to surmount these difficulties was the International Association for the Evaluation of Educational Achievement's Second International Science Study, begun in 1980 and just reaching publication now. Unfortunately, this study chose to test only students enrolled in the second year of high school physics, a group which in the United States is too small to allow detailed statistically-meaningful comparative analysis with our data. Nevertheless, limited comparisons can be drawn to allow a rough evaluation of the overall health and quality of physics instruction in our own country, relative to the other nations surveyed. (For further discussion, see Section XI.)

III. SURVEY METHODOLOGY

The initial task confronting the AIP when it prepared to carry out the survey was to develop a complete and up-to-date list of physics teachers from which a sample could be selected. The strategy used was to conduct a brief initial survey of high school principals to ascertain which schools had physics programs and the names of the physics teachers for those that did. From a well-regarded list of 23,161 schools with a twelfth grade maintained by the educational data firm of Quality Educational Data, Inc. (QED), we selected a sample of 3631 schools, stratified by size of school, type of affiliation (public, parochial or private), and geographic region, and then differentially sampled to ensure adequate representation of parochial schools and the largest public schools. After removing 153 schools which were found to have been improperly classified or had closed down, there remained a final sample of 3478 schools, representing a total estimated population of 21,700 public, Catholic and private schools across the nation which had a twelfth grade. Using QED data, corrected by information gathered from responding teachers wherever appropriate, we estimate that the population of schools had a total enrollment of 14 million students in the Spring of 1987, close to 3 million of whom were seniors, a figure that accords well with data available from other sources, for example, NCES' *Digest of Education Statistics*. (See Appendix A for a more complete discussion of the methodology used in this study.)

Our initial inquiry yielded responses from 3472 schools, with only six principals declining to participate in the study. Data from this query showed that 73% of these schools offered classes in physics that year, and another 9% taught it the previous year. [Weiss (1987: Table 6) found an almost identical percentage of schools offering physics for the 1985–86 school year.] The 18% of schools without physics classes were largely concentrated among schools with small enrollments. Thus 2.8 million seniors, or 93% of all seniors, attended schools which offered classes in physics in 1986–87. Of the 3301 teachers who were listed by the principals of these schools as teaching physics classes in the spring of 1987, just over 75% completed our survey questionnaire. Follow-up telephone calls to non-responding teachers produced data on physics classes and enrollments for a few percent more. (Non-respondents seem to match respondents very closely on distributions across the key school-level variables, including enrollment size and school type.) In order to derive the estimates for the entire population of schools presented in Table 1, we supplied weighted means, stratified by school type and size, for those cases where our data was incomplete. In all other instances, except as noted, data are reported in percentages and reflect the answers of responding teachers only.

IV. OVERVIEW OF SECONDARY SCHOOL PHYSICS INSTRUCTION IN THE UNITED STATES

"The root of the problem rests in the way our society views education as a whole. We are not geared toward material which might require thought and patient toil. Therefore many young people are steered away from the sciences . . . Japan places a high value on education. In 12 years . . . as a teacher, I have yet to see our society put such dedication toward education."

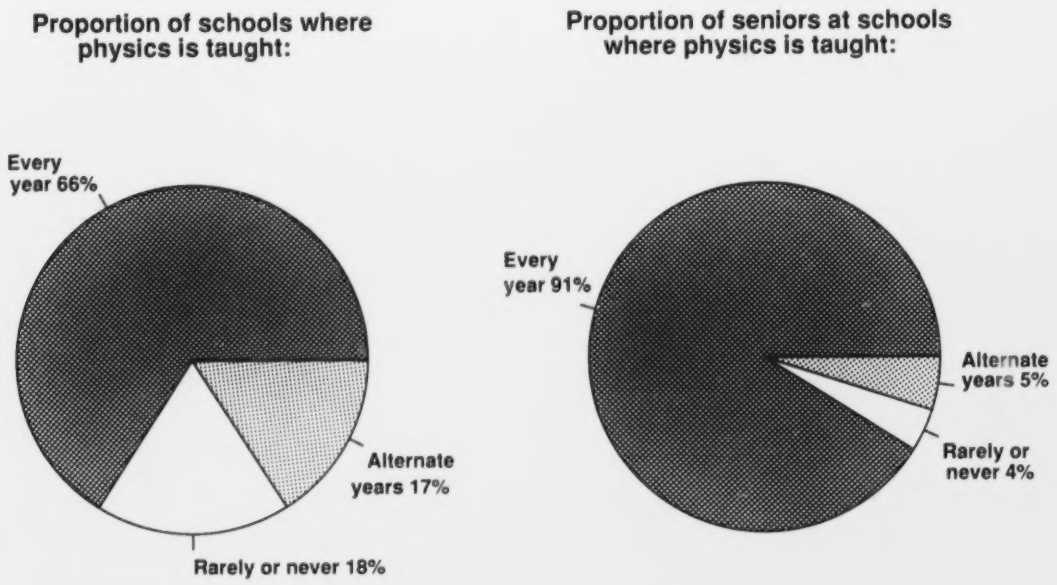
—A physics teacher from Pennsylvania

The responses we received to our teacher survey and the brief query addressed to school principals indicate that there were 17,900 teachers with physics assignments, teaching a total of 35,200 physics classes, in the 15,800 high schools offering physics as part of their curriculum during the 1987 spring semester. There were 623,600 students enrolled in these classes (some 21% of the seniors attending those schools and about 20% of all seniors). As a check, this figure is almost identical to the mean of responding teachers' estimates of the number of graduating seniors at their schools who will have taken at least one physics class by the time of their graduation.

Corresponding figures from the 1985–86 NSTA study were 19,000 physics teachers and 32,200 physics classes.[3] In the 1980 High School and Beyond Study, 550,000, or 18%, of the seniors interviewed said that they had taken or were taking physics.[4] Finally, the National Assessment for Education Progress study, conducted by the Education Commission of the States, found 487,000 students enrolled in high school physics courses in 1976–77, or 15% of attending seniors that year, while the follow-up Science Assessment and Research Project reported comparable figures of 504,000, or 17%, in 1981–82.[5] It should be noted that such discrepancies in percentages and numbers may well reflect different methodologies and definitions rather than meaningful differences in the data or trends over time. Rough support for such a conclusion might be drawn from the fact that reported figures for total enrollment in physics and the proportion of high school students taking a physics course seem to have been remarkably stable over the last several decades. AIP (1964: Figure 1) found 16,700 physics teachers and 400,000 students enrolled in high school physics in the late 1950s, and reported (1964: Figure 3) that the percentage of seniors taking physics stayed around the 20–25% range throughout the 1950s and early 1960s. Table 1 presents the estimated population parameters for physics, based on our own data, broken down by type of course.

By far the strongest association with whether physics is offered or not, and how frequently it is taught where it is offered, is school enrollment size. The extent of this association is reflected in Table 2 below. School size is also strongly related to type of school affiliation, with Catholic and especially private schools heavily concentrated among the smaller schools. Once the size differences are taken into account, the pattern of physics offering seems to be quite similar among schools of different types. Thus, physics is less likely to be offered only among the smallest schools in each category—nearly all of the remaining schools offer physics at least every other year. Among public schools, once senior class size rises to 200, physics is taught every year in virtually all schools. As a result, only 3% of public school seniors (and 4% of all seniors) attend schools where physics is not part of the curriculum, either on an every-year or an alternating-year basis (see Figure 1).

FIGURE 1. PHYSICS AVAILABILITY FOR SCHOOLS AND STUDENTS (all 3472 schools).


Proportion of schools where physics is taught:
Every year 66%
Alternate years 17%
Rarely or never 18%
Proportion of seniors at schools where physics is taught:
Every year 91%
Alternate years 5%
Rarely or never 4%

Even in rural areas, where the smallest public schools are overwhelmingly concentrated, over 90% of the students attend schools where physics is taught either every year or every other year. In view of the interaction between school size and type, and the overwhelming dominance of public schools in terms of overall enrollment (with 90% of all seniors), many of the subsequent tables in this section—especially those dealing with variables that show a significant correlation with size—will focus on public schools only, and a more complete discussion of physics education in parochial and private schools will be relegated to Section X below.

But while school size, above a certain enrollment level, seems to make little difference in terms of the presence of physics classes, it plays a large role in determining the extent and the breadth of high school physics programs. Table 3 shows that 82% of public high schools, with 67% of the seniors, offer only the regular first-year course in physics and/or physics for non-science students. But when we confine ourselves to just the largest schools—those with senior classes of 500 or more—over half are able to provide accelerated courses in physics, as well. Even more than sheer enrollment size alone, it is the presence of multiple physics teachers (itself, of course, strongly associated with school size) that seems to go along with the specialization entailed in a more diverse physics curriculum (see Figure 2).

As noted earlier, it turns out that the smallest public schools are overwhelmingly concentrated in the rural areas of the country (almost 90% of the public schools with fewer than 50 seniors are classsified as rural by QED), and especially

in the thinly populated states west of the Mississippi River (over 75%). What is more, the sparse school age population forces most of these schools to cover a broad range of grade levels—one-quarter of the rural schools include grades one through twelve, while another quarter have combined the junior and senior high grades. (In contrast, only 15% of urban and suburban public schools with twelfth grade include elementary or junior high grades as well). With such small enrollments and with their resources spread thin over many age groups, it is not surprising that virtually none of the rural schools offers a physics curriculum that goes beyond the basic first-year course. Indeed, given the fact that in many of these schools, the total number of seniors is smaller than the average class size in most urban and suburban high schools, it is to their credit that such a large proportion have committed themselves to managing that much.

FIGURE 2. BREADTH OF CURRICULUM BY NUMBER OF PHYSICS TEACHERS (1520 public schools offering physics with all teachers responding)

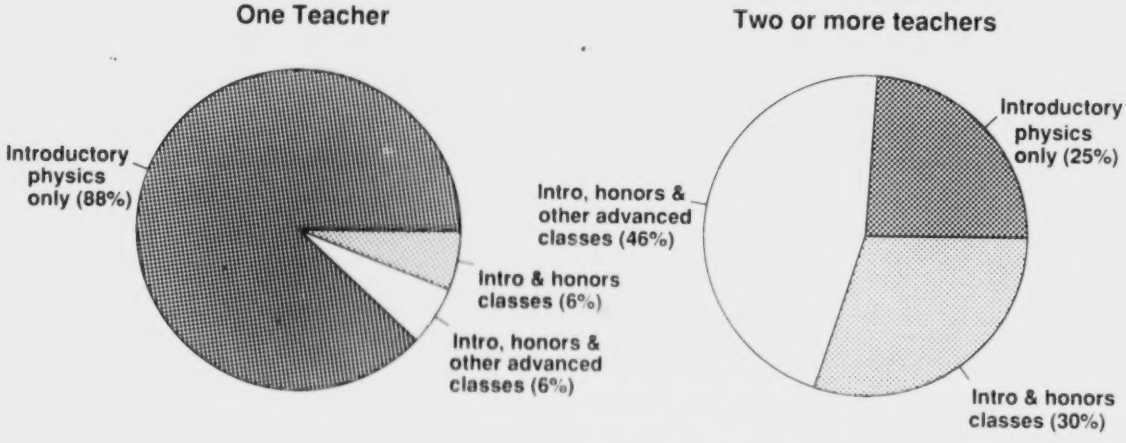

One Teacher
Introductory physics only (88%)
Intro & honors classes (6%)
Intro, honors & other advanced classes (6%)
Two or more teachers
Introductory physics only (25%)
Intro, honors & other advanced classes (46%)
Intro & honors classes (30%)

Table 4 presents basic descriptive findings for a number of additional aspects of the physics programs at public high schools. [Table 4 represents the 1603 cases (78%) out of the sample total of 2051 public high schools with physics where at least one teacher responded to the survey.] The figures on minimum graduation requirements in science closely mirror the findings from the *Public High School Graduation Requirements* survey of school districts, conducted in 1985 for the Office of Educational Research and Improvement of the U.S. Department of Education. That report noted the recent trend toward rising requirements, largely in response to the National Commission on Excellence in Education's *Nation at Risk* study three years earlier. The slightly higher level of requirements found in our own survey may reflect additional requirements added on by individual schools. It is also worth noting that the 15% of sample schools where the teachers reported the presence of a formal program to increase physics enrollments did not seem to attract substantially more students to physics than schools without such programs.

Turning to a closer examination of the 12% of public schools where teachers report that minority group students comprise over half the total enrollment, we find that, as expected, these schools tend to be somewhat larger and more concentrated in urban areas than schools with white majorities. There are also a fair number of smaller schools with minority concentrations scattered across the South and Pacific regions of the country, where substantial numbers of Black and Hispanic Americans, respectively, still live outside of major cities. Interestingly, the findings suggest that, in some respects, many schools with large minority enrollments seem relatively well-positioned to offer an extensive program in physics. Minimum graduation requirements in science at these schools are, on the average, slightly higher than they are at mostly white schools. Teacher salaries are comparable, and slightly higher budgets are allotted per physics class for equipment and supplies. In addition, a somewhat greater choice of physics-related extracurricular activities are available to individual students and to classes (although this may be partly an artifact of the larger average school size among schools with predominantly minority-group students). Moreover, teachers at these schools report feeling better prepared than their counterparts at other schools to deal with interpersonal relations vis-à-vis their students. (Unfortunately, the questionnaire did not ask teachers about their own ethnic status.)

Nevertheless, these same schools seem to show the effect of the economic and academic disadvantages suffered by their communities. Teachers report fewer students going on to college, and are more likely to complain about inadequate preparation in reading and especially mathematics among their physics students. More teachers also cite the lack of parental involvement and community support as a problem in their physics teaching. And, most importantly for our study, the proportion of students enrolling in physics is lower. When we focus in on schools located in metropolitan areas (where almost three-fourths of the schools with predominantly minority-group enrollments are located), the percentage of students taking physics in schools with fewer than 5% minority enrollment is about 40% higher than in schools where more than half of the students belong to minority groups. The findings here would seem to support those found elsewhere (e.g., Koretz,1987) which suggest that the obstacles to full educational

equality have deep roots in historical experience and social structure, and are not likely to be overcome simply by further raising academic requirements or current expenditures, although these may be necessary ingredients in a long-term process of change.

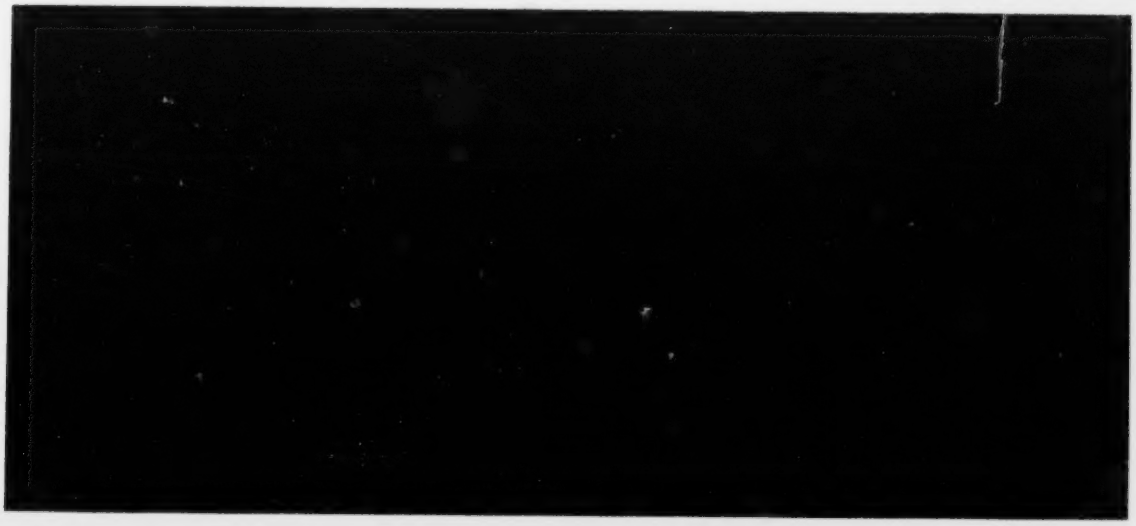
Differences in the contours of physics instruction show up in the data not only among schools of varying racial composition, but also between different

geographic regions of the country. Not unexpectedly, the contrasts are strongest between the states in the southeastern quadrant of the nation (with the exception of Virginia and Florida) and the rest of the nation. Schools in these states pay lower salaries to their physics teachers, hire teachers with fewer college physics courses in their background, are more likely to use teachers whose primary field is in another discipline to teach physics, and allocate less money per physics class for supplies and equipment. Similarly, while schools outside the South are, on average, only slightly bigger than their southern counterparts, they are much more likely to offer physics courses beyond the basic introductory class. Almost twice as many northern and western schools send at least 70% of their graduates on to college. And, most importantly for the discussion here, public schools in the North and West enroll 20% of their students in physics, while the comparable figure for the South is only 13%.

On the other hand, there were a few findings that seemed to run in a direction opposite to the one just discussed. Respondents from southern states offered a greater variety of physics-related extracurricular class activities than was reported by teachers in other sections of the country. Even more striking, southern schools turned out to have slightly higher minimum graduation requirements in science than northern and western schools—a finding similar to that reported in the study on public high school graduation requirements cited above. These changes in science requirements are of recent vintage—according to the *New York Times* (8/10/87:A-14), "As recently as 1980, 10 of the 15 states that belong to the Southern Regional Education Board required no science or only one year of it in high school; today every state requires at least two years, some three years, of science." It may thus well turn out that these recent reforms will, over the coming years, serve to reduce the regional differences in physics enrollments just described.

The above paragraphs lay out the extent and basic structure of the physics programs that are available to high school students. But it is quite another matter to look at who actually takes physics. As noted earlier, through two independent items in our questionnaire, we were able to estimate that only 20% of high school graduates (and only 19% of those from public high schools) have taken a physics course by their senior year. Curiously, while larger schools are much more likely to offer physics than smaller schools, there is no such difference in physics enrollment percentages among public schools that do offer the subject. In fact, there is a slight tendency for the largest public schools to have a lower proportion of students enrolled in physics than their smaller counterparts. This is unexpected, especially since, as noted above, it is precisely among the biggest schools that physics programs tend to be the most diverse and thus should be most capable of tailoring courses to the needs of different groups of students. Table 5 illustrates that the breadth of the physics curriculum does indeed have a substantial effect on the size of student enrollments in the subject. Controlling for this factor brings to the surface an even more pronounced decline in the proportion of students taking physics as school size increases.

Like the interaction with school size, the relationships between physics enrollments and other structural characteristics of schools also turn out to be as



complex as they are important for understanding the underlying character of physics education in our society. For example, we already noted that schools in the southern quadrant of the nation enroll substantially fewer students in physics than northern or western schools do, as do schools with heavy minority group enrollments relative to all-white schools. When we take these two factors—region and race—in conjunction, however, it turns out that they interact in a complex fashion. The real difference between the south and the rest of the nation resides almost entirely in the schools with white majorities, while students at schools with predominantly minority enrollments exhibit similar proportions of students taking physics regardless of location. In fact, although minority schools in the north and west show a lower proportion taking physics than schools with white majorities, in the south the relationship is actually reversed, with schools that are composed primarily of minority-group students reporting comparable or even slightly higher enrollments than predominantly white schools. While it might be argued that this finding is an artifact of the fact that a higher proportion of southern schools are located in rural settings, it turns out that the relationship holds regardless of whether urban or rural schools are considered.

Finally, it is likely that one of the common threads running beneath the contrasts by region, racial composition, and urban/rural setting is social class. While it was virtually impossible to obtain an accurate reading of the average socio-economic standing of students from a survey of teachers, the question regarding proportion of graduates going on to college might be taken as an extremely rough stand-in for the overall socio-economic level of the student body. (Since it appeared rare that physics was a required course even in those schools where virtually all seniors went on to higher studies, it seemed reasonable to assume that physics-taking and matriculation into college were measures that were free to vary independently.) As it happens, there was a strong overall association between percentage going on to college and percentage taking physics, and it held for schools from both rural and metropolitan settings as well as for schools of varying minority composition. (Curiously, however, the relationship did not hold for schools in the South, although it was strong among schools throughout the rest of the country.) These rough indications suggest that these four interrelated factors—race, region, metropolitan setting, and social class—probably have a

significant independent impact and an even stronger conjoint influence on the size of physics enrollments across the nation. Confirmation of this conclusion and fuller specification of the interaction between the factors will have to await the introduction of more precise measures of student socio-economic standing in follow-up studies.

There are also hints in the data that high schools may be in the process of becoming increasingly polarized in terms of the size and health of their physics programs. Those high schools where teachers reported a decrease in physics enrollments over the past five years showed average enrollments at levels that were substantially below those schools where teachers noted stable or increasing enrollments. To the extent that teachers' observations on enrollment change reflect an ongoing process rather than a completed one, it may signal the growth of even greater disparities over the coming years.

The results just discussed, while raising as many questions as they answer, address the questions that lie at the heart of this inquiry. Pinpointing the differences between the four-fifths of high school students who never take physics and the fifth who do leads directly into the issue of physics literacy in the population (and the electorate) as a whole. Similarly, focusing on the reasons why the bulk of students who do take physics have only the basic introductory course available to them brings up questions of background and preparation among the pool of students from which most future college physics majors (and many future physics teachers) are drawn. [AIP's own surveys of physics bachelors degree recipients (Ellis,1988:Table III) and physics graduate students (Ellis,1987:Table I) found that 88% and 93%, respectively, had taken physics in high school. However, only 16% of the former had had the advanced placement high school course.] We will return to examine these issues more fully below, after we have had a chance to review the data on teacher characteristics.

V. DEMOGRAPHIC PROFILE OF HIGH SCHOOL PHYSICS TEACHERS

"We are a strange breed of 'rare birds.' No one ever quite knows what to do with us, but any one of us who are good teachers plus good scientists are worth our weight in gold."

—A physics teacher from Pennsylvania

Of the 3301 physics teachers whose names were supplied by the high schools where physics was taught during the 1986–87 academic year, 2485 completed AIP's 12-page questionnaire. Based on these responses, the following picture emerges:

- More than three-fourths of the respondents were male (a proportion similar to that found in the NSTA study), and respondents had a median age of 41 and 15 years teaching experience. [Weiss (1987:Table 36) reports comparable findings in age and teaching experience for all high school science teachers.] We found a slight tendency for women teachers to be concentrated in smaller schools and in Catholic schools, and for teachers with the least overall teaching experience to be clustered in smaller schools. (See Section VIII for related findings on salary levels and retirement plans.)

- Respondents had an average of ten years' experience teaching high school physics. About one-half (47%) of the teachers have taught physics as long as any other subject in their secondary school teaching career, with the proportion being notably higher in larger schools.

- Turning to the academic credentials of teachers in the sample, we found that almost two-thirds of the respondents held graduate degrees. [Again, this was a similar proportion to that found by Weiss (1987:Table 38) for all science teachers, and a somewhat higher proportion than holds for all pre-college teachers nationwide (Evangelauf,1987:A-50).] However, only about one-fourth of the respondents in our study appear to have actually earned a degree in physics, including 11% with a graduate degree in the subject. (Problems with the question on academic background, including teachers listing multiple majors or areas of specialization, mean that these findings should be interpreted with caution, and that the proportion who actually hold degrees in physics may be lower than reported.)

- Still, those teachers without physics degrees reported taking an average of about five semester-length college courses in the field. Once again, teachers who earned a degree in physics and those with the most extensive course background in physics tend to be overrepresented in the larger schools.

- In addition to academic background, one-quarter of the teachers reported having had non-academic physics-related work experience. The mean duration of this experience was almost six years.

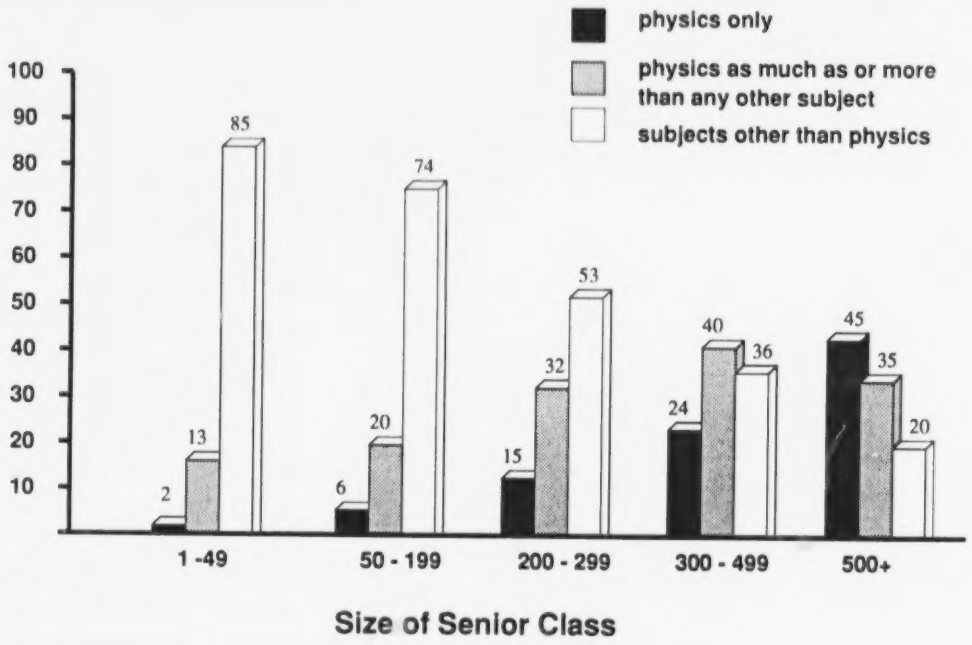
- Despite the respondents' years of experience with physics teaching and their academic backgrounds, however, few could accurately describe their careers as being primarily devoted to the field. For example, some 70% report having begun their teaching career in a specialty other than physics. (The other initial specialties by far most frequently mentioned were math, chemistry, and biology, cited by 20%, 19% and 17% of the teachers, respectively.)

- Even more striking, only 13% of the respondents had teaching assignments in physics alone last year. A similar number concentrated more on physics than on other subjects, while another 9% divided their time equally between physics and another primary field. The remaining teachers, almost two-thirds of the total, had their primary concentration of current classes in a field other than physics. Chemistry (21%), math (16%), and general and physical science (17%) were the concentrations from which teachers were most likely to be recruited for physics assignments. The distribution of subjects in physics teachers' current loads found in our own data was very similar to that reported in the NSTA study (Aldridge, 1986: Appendix I).

- Along the same lines, the NSTA figure for the proportion of physics teachers with only one or two classes in physics (83%) was relatively close to our own figure of 76%. That this is a situation of long standing can be seen in the fact that a similar percentage (81%) was reported in the AIP handbook on physics education (1964:16) a quarter century ago. As that report noted then, the inability to specialize in the field cannot help but have an influence on the training and career plans of prospective physics teachers. As they put it, "The student interested in teaching physics cannot concentrate in this field as much as he [sic] might like, because he must be prepared to spend most of his time teaching some other subjects....Most teachers specialize in some other subject and then take the minimum number of courses which will allow them to teach physics."

- As we noted earlier, the fractionalized character of most respondents' teaching loads can be accounted for in large measure by the relatively small size of student enrollments in physics. Further evidence for this conclusion can be seen in the rather strong relationship between subject concentration and overall school size (see Figure 3). In contrast to the 13% figure for all teachers, in the largest schools almost half the physics teachers taught physics exclusively, while another quarter had most of their course assignments in physics. On the other hand, fewer than one physics teacher in twenty working at the smallest schools taught mostly or only physics.

FIGURE 3. CONCENTRATION OF CURRENT TEACHER CLASS ASSIGNMENTS IN PHYSICS



This brings us to the rather sticky issue of certification. In response to the item on certification in the questionnaire, 68% of the teachers reported that they were certified to teach physics, while 6% have provisional certification. (Another 6% state that they are certified in physical science, and most of the remaining 20% of the teachers have certification in mathematics or other sciences.) Unfortunately, teacher certification regulations vary widely from state to state. Some states do not have a separate certification category in physics, but rather lump all of the physical sciences (or even all of the sciences taught in secondary school) together. Private and parochial schools also have markedly different regulations governing certification than the public schools. In light of this, it is unlikely that all of the teachers responded on the same basis—in particular, some may have considered certification to teach physics to be part of their broader certification in secondary school science.

Thus, in order to get some idea of the extent to which a teacher's career has been characterized by a specialization in physics, we constructed a measure that was independent of the certification item, depending instead on both initial training or specialization in the field and on substantial teaching experience over the course of the teacher's career. In order to qualify as specialists by this measure, teachers would either had to have earned a degree in physics or have started off their teaching career with physics as their specialty, and would subsequently had to have taught physics as long or longer than any other subject, or else have taught physics in at least two-thirds of the years spanning their career.

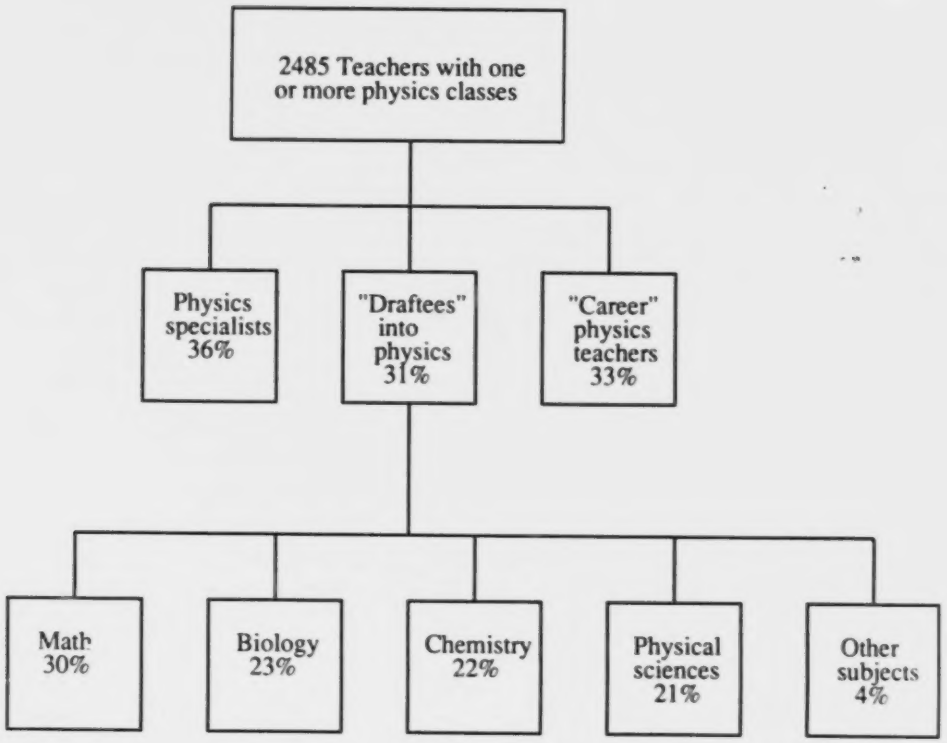
Data from AIP's 1986–87 survey of physics bachelors degree recipients (Ellis, 1988: Table VIII) indicate that, of the 39% of physics undergraduates going di-

rectly into employment, only about 6% choose high school teaching. Some of the explanation for this small percentage may be found in the fact that the $18,000 per year median starting salary these teachers report is well below the salary levels of their counterparts going into other types of employment. This is in part the product of a sitution in which, over the previous decade, starting salaries for the latter group more than doubled, while starting salaries for physics bachelors recipients entering high school teaching increased by only 44%. Even more striking, AIP's 1985 Salary Report for members of affiliated societies shows that even after more than twenty years experience, the median salary of society members with Masters degrees who teach high school physics does not equal the median earnings level of Masters recipients who are just out of school and beginning physics careers in private industry (Skelton *et al.*,1987: Table 19).

While this situation works to limit the number of high school physics teachers who have actually earned an academic degree in physics, it should be recognized that there are many teachers with little formal accreditation who nevertheless have spent numerous years teaching physics and who have by experience acquired considerable mastery of the field and the methods of teaching it. In order to accommodate this group, a second category of "career physics teacher" was created, encompassing teachers whose degree and initial specialty was in another field, but who have taught high school physics for ten or more years or for at least two-thirds of their teaching careers. The remaining teachers were those who by both training and experience had specialized in other fields, and who have been "drafted" into the ranks of teachers of physics on only an occasional basis.

It turns out that about one-third of the teachers with physics classes fall into each of these categories (see Figure 4). Among the "draftees," the largest proportion (30%) come from math teaching backgrounds, while 23% are biology teachers, 22% are drawn from chemistry, and 21% come from the other physical sciences (including the junior high school level science courses). Only 1% of all physics teachers (4% of the "draftee" category) are clearly recruited from all other subject areas combined, although there are an additional 11% whose backgrounds straddle more than one subject area, and thus cannot be unambiguously fitted into any of the categories.

FIGURE 4. AREAS OF SPECIALIZATION OF HIGH SCHOOL TEACHERS OF PHYSICS



VI. PHYSICS TEACHING AS A PROFESSION

"I actively discourage students of mine from considering science education as a career. The low pay, lack of recognition, poor opportunity for advancement, and inherent job frustrations make science teaching, in my opinion, a poor choice for someone just leaving college."

"We should advertise the value of physics teaching not only as an intellectual pursuit, but as a marvelous lifestyle! It's FUN!!"

It is widely accepted that secondary school science teachers face a professional situation in which they have to master two different sets of skills—pedagogical techniques and scientific knowledge—and use them in often inhospitable circumstances in exchange for a salary far below the average for professionals with equivalent training in related fields, as well as career opportunities which are

limited at best. AIP's physics teacher survey contained a number of items with direct bearing on the teachers' experience and assessment of their professional careers.

- A small but not insignificant proportion (21%) of the respondents has taken on administrative duties in addition to the demands of teaching. While these tasks range from school computer coordinator to principal, about 60% of these teacher-administrators are concentrated in one position—science department chairperson. Private and Catholic school teachers were somewhat more likely to fill an administrative role than their public school counterparts.

- A much larger number—almost two-thirds—of the teachers have also taken on responsibility for supervising a wide range of student extracurricular activities. Twenty-three percent of the respondents were class sponsors, 16% sponsored one or more science clubs, and, perhaps most surprising, 18% supervised athletic teams.

- The mean full-time, academic-year salary for respondents was $25,400. Public school teachers received, on average, substantially higher salaries than teachers in private and Catholic schools. (Clergy receiving small stipends and "religious salaries" were excluded from the latter.) There was an even stronger positive association between salary and enrollment size, with teachers working at the largest schools—those with more than 500 seniors—receiving two-and-a-half times the salary of those at the smallest schools (see Figure 5). These results held despite the finding on administrative functions reported in the previous paragraph and the fact that administrators tended to have somewhat higher salaries than those with only teaching duties. (See Section VIII for further discussion on salary.)

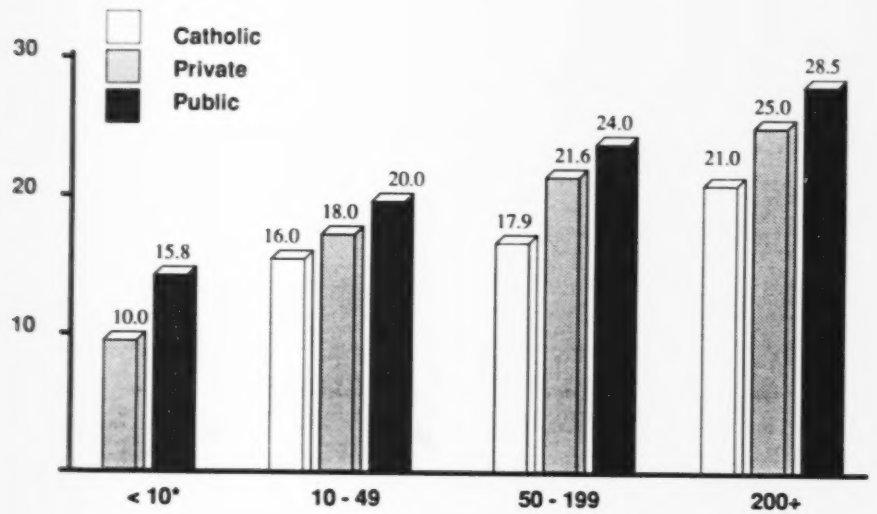
- On the whole, respondents indicated that they were largely self-supporting. On average, teachers reported that their school salary contributed 70% of their total household income. In addition, about three-quarters of the respondents reported earning income from one or more other sources. (For the percentages reporting income from the different sources specified in the instrument, see Table 6.)

- There was an overwhelmingly favorable response to an item about overall career satisfaction, although this finding should be taken with a grain of salt, since it has been frequently shown that such global queries on satisfaction almost invariably produce more positive responses than questions referring more concretely to specific aspects of a job or an experience. This being said, it turned out that three-quarters of the respondents rated themselves as satisfied or highly satisfied with their teaching career, while most of the remaining fourth reported mixed feelings, and only a few teachers expressed outright dissatisfaction. (Almost identical figures, derived from a slightly dif-

ferent scale, were reported by the Department of Education's Center for Educational Statistics, based on data collected from teachers generally in a 1985 Harris poll conducted for the Metropolitan Life Insurance Company.) It is interesting to note, especially in light of the salary results, that teachers at public schools and large schools expressed the highest levels of dissatisfaction.

- One-third of the respondents indicated that they planned to continue their high school teaching career right up to retirement, and half indicated they would probably do so, while the remaining sixth reported that they would probably not stay with teaching. Teachers in public schools and larger schools were somewhat more likely to plan to remain as teachers, a pattern that seemed consonant with their higher salaries but appeared to clash with their higher levels of dissatisfaction. In a related question, 34% of the respondents reported that they were currently considering a career change, although they weren't actively pursuing an alternative at the moment, while another 6% indicated that they were actively working on such a change. Unlike the question on retirement, there was little variation here by school type or size.

FIGURE 5. MEDIAN BASE SALARIES OF PHYSICS TEACHERS BY SIZE AND TYPE OF SCHOOL (in thousands of dollars)



*For Catholic schools with less than 10 seniors, numbers too small to calculate statistics

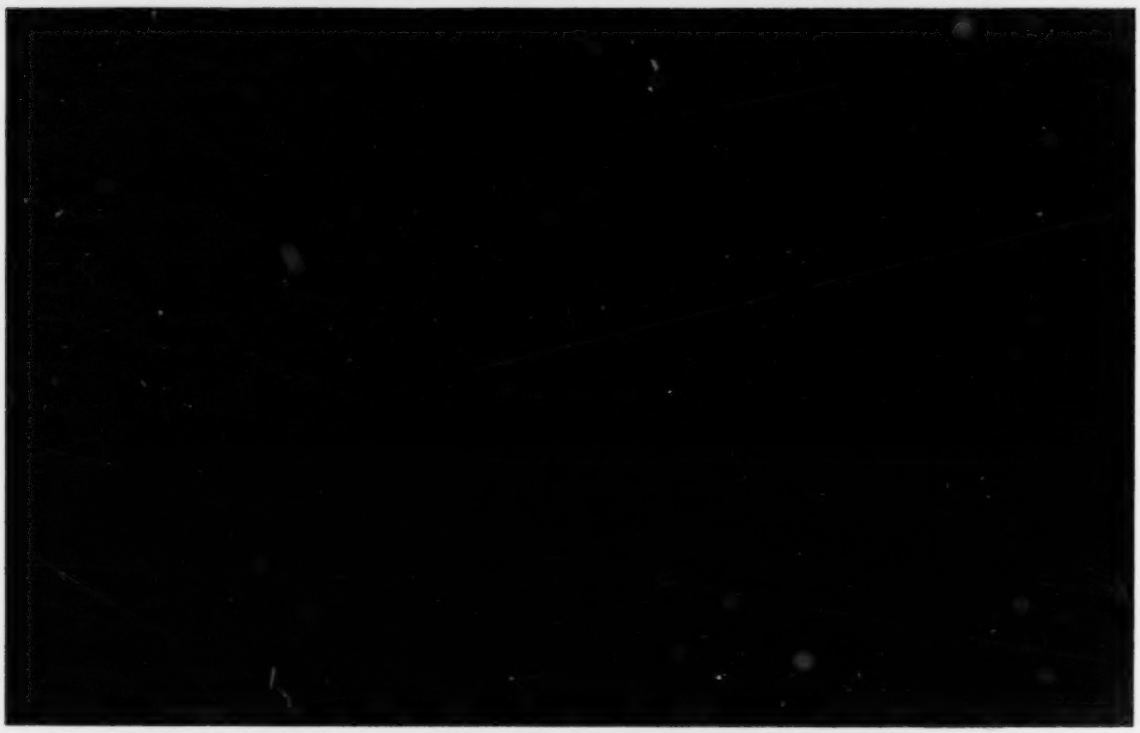
Given that salary levels are strongly related to seniority, an attempt was made to look at differences in earnings above a certain base level after adjusting for years of teaching experience. In light of different compensation patterns between schools of different types, we decided to focus more closely on public schools. (Since the questionnaires did not ask teachers about their initial salaries when entering teaching, the new salary measure corrected for seniority was not able to separate the effects of different starting salaries and subsequent average annual rates of increase.) Not unexpectedly, teachers with graduate degrees (and especially the few holding PhD's) show higher earning levels on the new measure than their counterparts with similar years of experience who hold only the bachelors degree. Furthermore, teachers with a strong academic background in physics seem to do better than teachers with physics classes whose training was primarily in another field. While we have no direct measure of the socio-economic level of the school community, it turns out that suburban schools pay higher salaries for teachers with comparable experience than do urban and especially rural schools. The same finding holds for larger schools and schools which send a high proportion of their graduates onto college, relative to smaller and less academically favored schools. Finally, it is worth noting that the public schools which favor their physics teachers with the highest salary increases also tend to enroll the highest proportion of students in physics.

VII. THE QUALITY OF TEACHING: ATTITUDES, OBJECTIVES, AND PROBLEMS

"...upon my arrival this year to teach physics, I found lab equipment for physics was practically non-existent."

"In my seven years here I have met with much satisfaction and a fair amount of success in building up the program. I have a great deal of support and respect from the administration."

The questionnaire devoted considerable space to trying to tap into the teachers' qualitative sense of achievement and difficulty as well as the more structured and formal aspects of the physics teacher's job. Teachers were asked to rate a list of 19 commonly encountered problems in physics teaching in terms of their own experience, and to rank their top three teaching objectives out of a list of nine. Table 7 lists the six problems which stood out as being cited most frequently and being viewed as most serious: three involve the tools teachers are given to teach with, two revolve around the qualities of the students being taught, and one echoes the familiar complaint of all teachers regarding insufficient preparation time, especially relevant in physics because of laboratory preparation.

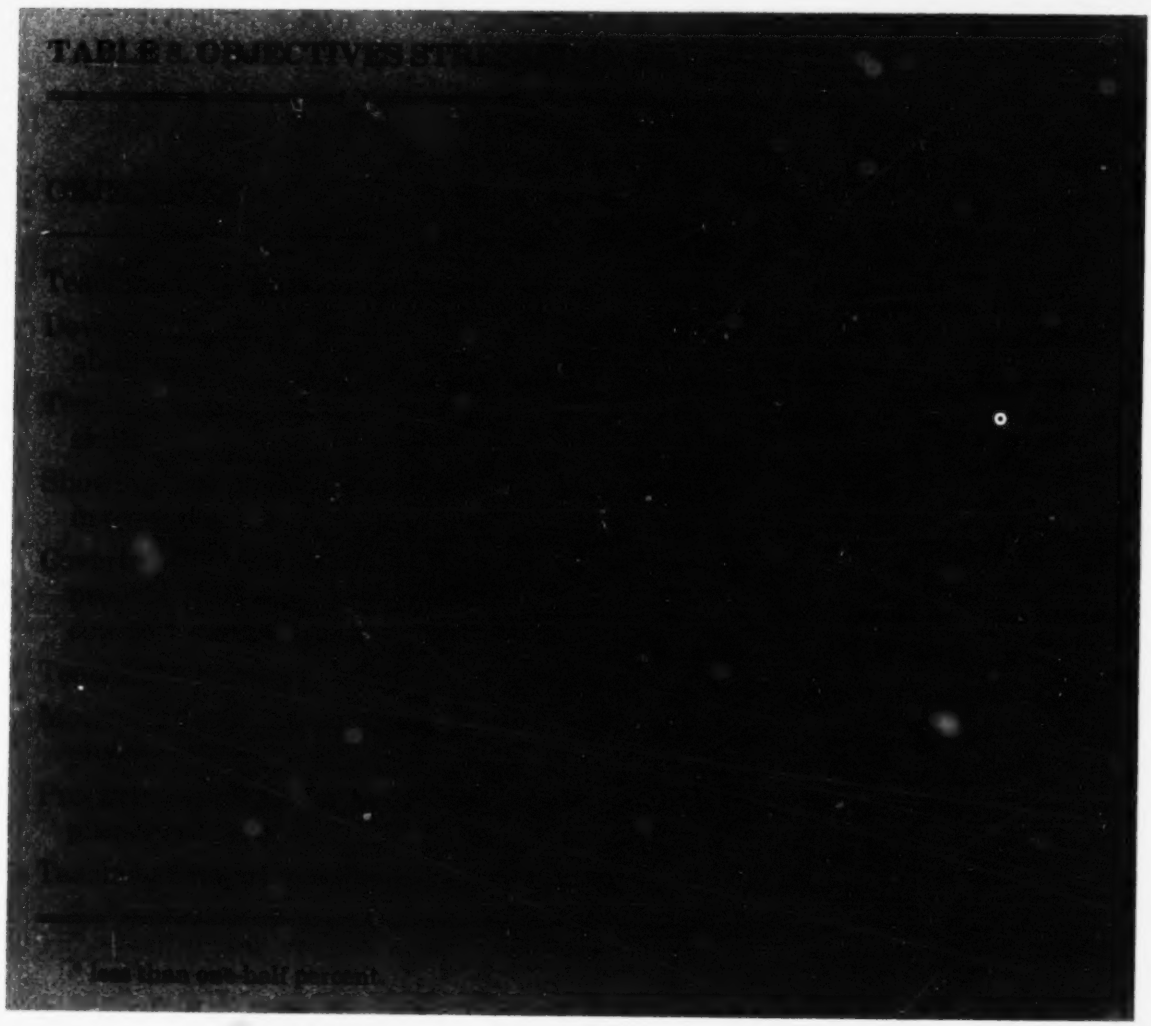


In contrast to the commonly cited problems in Table 7, very few teachers reported that they had difficulties maintaining student discipline, or that they had problems with class size or with the quality of the textbooks they used (see section IX for further discussion). Overall, teachers who felt they had less influence over different aspects of their teaching functions tended to report greater numbers of serious problems than teachers who felt they had more control over their work. Teachers reporting more serious problems were also, predictably, far more likely to express overall dissatisfaction with their teaching careers, and were also somewhat more likely to plan to quit teaching prior to retirement. The group reporting the greatest number of serious problems was also weighted towards younger teachers, especially those in the first five years of their careers.

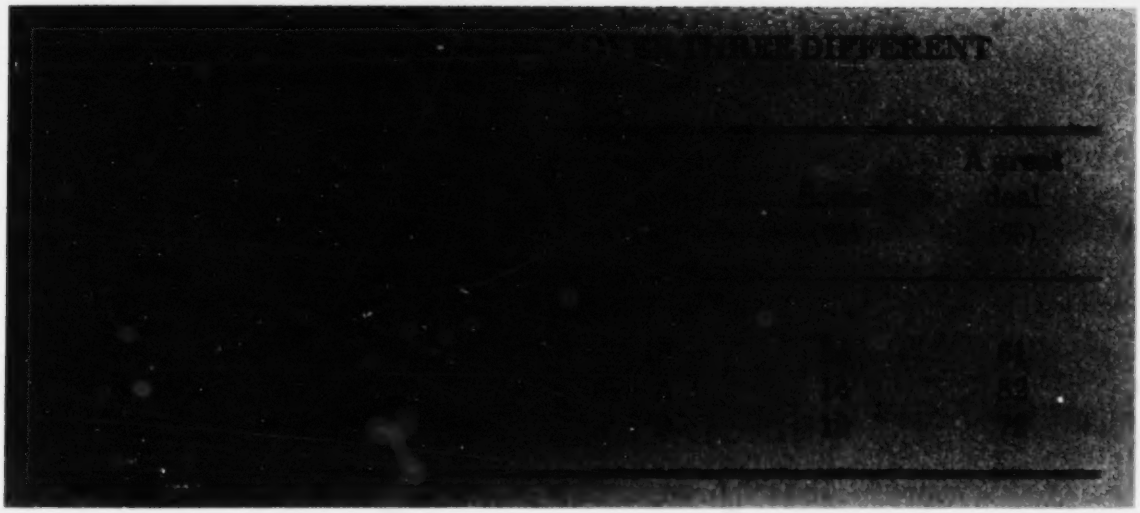
It is also noteworthy that public school teachers reported more serious problems than teachers in Catholic or private schools. The largest differences were in items regarding perceived support—public school teachers reported a more disturbing lack of support from school administrators, parents and especially community members. They also complained more about lack of student interest in

physics, and lack of school encouragement for science instruction. Finally, public school teachers were more likely than private or Catholic school teachers to mention low enrollments in physics as a serious problem, a perception that will find corroboration in the figures on percent of students enrolled in physics in schools of different types in Section X below.

Table 8 presents the relative rankings of the nine objectives teachers were asked to rank. The two objectives to which teachers most often gave priority both focused on teaching the basics rather than on transmitting sophisticated material to advanced students. A third, less strongly stressed, illustrated teachers' efforts to respond to the lack of students' math background cited in the problems list.



Teachers were also asked about the extent to which they felt they had influence over three different aspects of their physics teaching activity. As illustrated in Table 9, respondents generally indicated a strong sense of control over these aspects of their work.



But while these overall levels of perceived influence may appear to be relatively high, there is a good deal of variation among schools of different types and in different geographical settings. In states like New York, where responding teachers reported average levels of influence far below the national norms reflected in Table 9, a state-wide education policy task force recognized lack of teacher influence as a major problem, and concluded that schools need to be "restructured to give teachers a greater decision-making role in areas ranging from textbook selection to hiring practices" (*New York Times*, 3/11/88: B4).

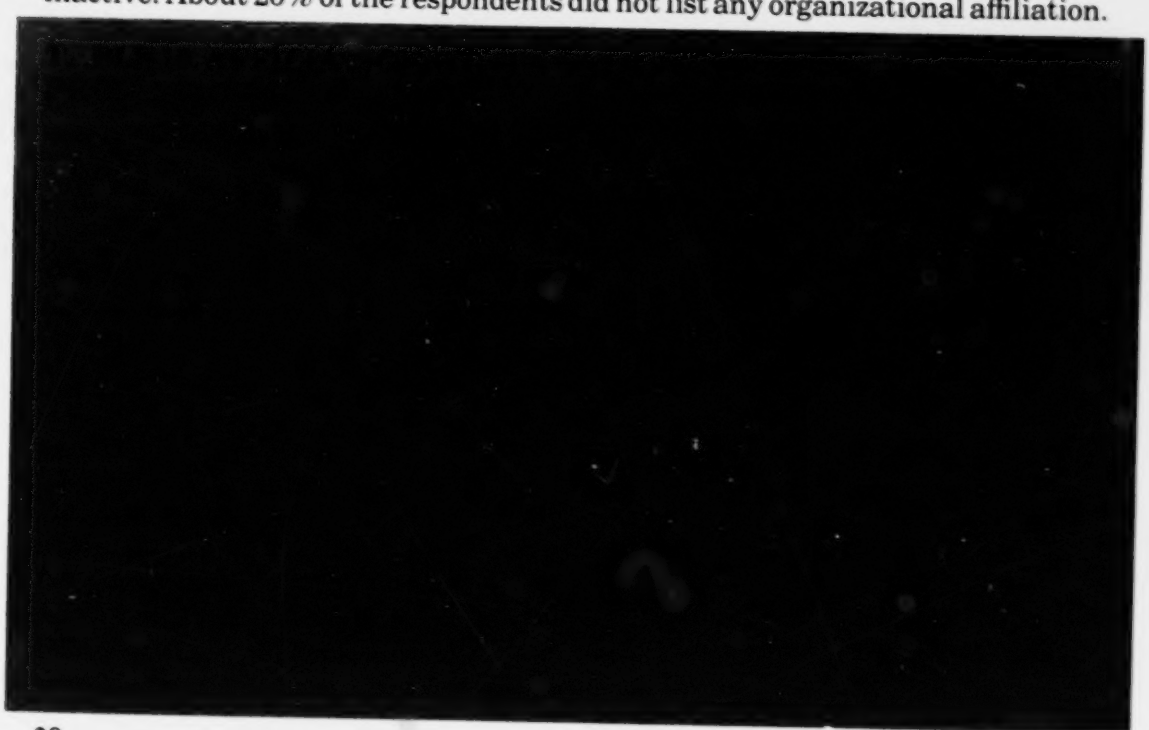
The questionnaire also devoted considerable space to probing the variety and extent of teachers' professional activities outside of school. Asked about where they turned to keep up with current developments in the field of physics and in physics education, teachers overwhelmingly cited scientific journals (79%) and the mass media (70%) in general. Somewhat smaller numbers reported availing themselves of professional meetings, school-year workshops and summer science institutes to keep current in the field (although a high proportion of those attending summer institutes indicated that the information they had gleaned there had proved especially helpful in subsequent teaching). At the other extreme, a very small percentage turned to school science specialists at the state or district level, and few of those who did reported finding them especially helpful.

Given the importance of scientific journals as sources of information, the questionnaire asked teachers to indicate whether they were regular readers of eleven magazines and journals spanning physics, science education, and general interest science. Periodicals in this last category, especially *Discover* (cited by 45% of the teachers) and *Scientific American* (cited by 40%), turned out to be most widely read. Close behind, and especially helpful in the physics classroom, was *The Physics Teacher*, published by the American Association of Physics Teachers. Of the journals listed, *Physics Today*, *Science*, *Science Digest*, *The Science Teacher*, and *Science News* were each cited by 20% to 25% of the respondents.

Attendance at professional meetings, institutes and workshops also came in for greater scrutiny on the questionnaire. Just over half the respondents reported attending professional meetings over the preceding two years, with the average being a bit higher than one meeting per year. Almost as high a proportion attended science workshops during the course of the school year, and again the average was just over one workshop a year. Fewer respondents (30%) had enrolled in summer science institutes or workshops during the prior twenty-four months. All in all, about 70% of the respondents had attended at least one of these forums during that time period. Seven out of eight teachers attending these functions received some form of support or compensation for their activities. Forms which such support took included:

- released time from teaching (61% of respondents);
- reimbursement for travel or per diem expenses (46%);
- professional growth credits (34%);
- stipend from non-school sources (27%);
- stipend from respondents' school or school district (19%).

Table 10 indicates the range of professional organizations with which respondents maintained affiliation, as well as the average level of involvement with each organization. Included in the "other organizations" category was The American Physical Society—as it turned out, only 1% of the responding teachers reported membership in APS, and virtually all of them described themselves as inactive. About 20% of the respondents did not list any organizational affiliation.



Finally, the questionnaire asked teachers to describe the extent of their personal and professional contact with colleagues in and out of school. Table 11 shows their responses, as well as the proportion desiring greater contact with each group. Predictably, interaction is greatest with fellow teachers inside the respondents' own schools. That level of interaction falls off sharply, and the desire for greater contact rises concomitantly, vis-à-vis academic counterparts in other high schools and in higher education. The degree of contact is weakest with scientists working in a non-academic setting, and it is also with this group that the desire to increase contacts is strongest.

We went on to examine the impact of involvement in professional development activities on contact with colleagues working in other settings. Not surprisingly, attendance at professional meetings, school-year workshops and summer institutes seems to make a significant difference in the level of such contact. Attendance at professional meetings brings the greatest increases in contact with science teachers at both the high school and college level. School year workshops were associated with greater contact only with other high school teachers, while summer workshops and institutes appeared to have an impact especially on interaction with college and university faculty.

Another predictable influence on extent of contacts is organizational membership. Belonging to professional groups like the National Science Teachers Association and especially the American Association of Physics Teachers has a significant impact on levels of interchange with physics or other science teachers at other high schools. In the case of AAPT, members were also somewhat more likely to report greater frequency of contact with counterparts at the post-secondary level.

Table 12 presents respondents' reactions to five controversial policy or program proposals that have been forwarded from various quarters in recent years.

[For example, the New York State Task Force on the Teaching Profession whose report was cited earlier in this section also, according to the *New York Times* (3/11/88:B-1), considered "a requirement that all prospective teachers pass an examination on the subjects they would teach."] Not surprisingly, teachers were in general more favorably disposed to proposals that would improve their working conditions or bring them recognition than they were towards proposals that could jeopardize their certification or introduce competitors for their jobs. Nevertheless, it is worth noting that almost as many teachers seemed to favor competency tests for themselves and their present colleagues as registered opposition to the idea. [Weiss (1987:Table 74) found that similar proportions of high school science teachers expressed agreement with the proposals for competency tests for experienced teachers and for supplementary pay. She found a slightly higher percentage favoring competency tests for prospective teachers.]

VIII. GENDER, SPECIALIZATION AND SENIORITY: IMPENDING CHANGES IN THE RANKS

"I have found my students increasingly interested in physics, yet have encountered problems with male faculty who find it difficult to relate to a woman in science, let alone chemistry or physics."

—A teacher from Wisconsin

"I have been pressed into teaching physics on an emergency basis. Even so I am better able to do so than my predecessor, who lacked any physics background. I am appalled that I have been allowed to teach physics with such poor preparation."

—Physics teacher from a midwestern high school

The previous three sections offer a broad descriptive outline of the corps of secondary school physics teachers in this country, but they only hint at the linkages to broader social and educational structures that may help us to understand

why physics teachers have the characteristics they do. For example, our findings suggest that somewhere around one-quarter of physics teachers are women, despite the fact that, for high school teachers as a whole, the figure is closer to 50%. This is not so surprising, given the historical pattern—resulting from discrimination and the force of social tradition—which kept many women from pursuing or even considering a career in physics or the other "hard" sciences. There is some evidence that changes in these patterns are beginning to occur. Nevertheless, it is the patterns themselves that currently dominate the landscape, and will continue to do so for some time to come. Given the wide recognition of the shortage of qualified physics teachers [Weiss (1987: Table 72), for instance, found that almost three-quarters of the principals in her sample reported difficulty in finding qualified physics teachers to fill vacancies], it is important to recognize and remove the obstacles to broad and effective recruitment of the best potential candidates. (While the questionnaire did not ask teachers to identify their ethnic origins, similar observations would probably be in order regarding minority group teachers as well.)

GENDER DIFFERENCES

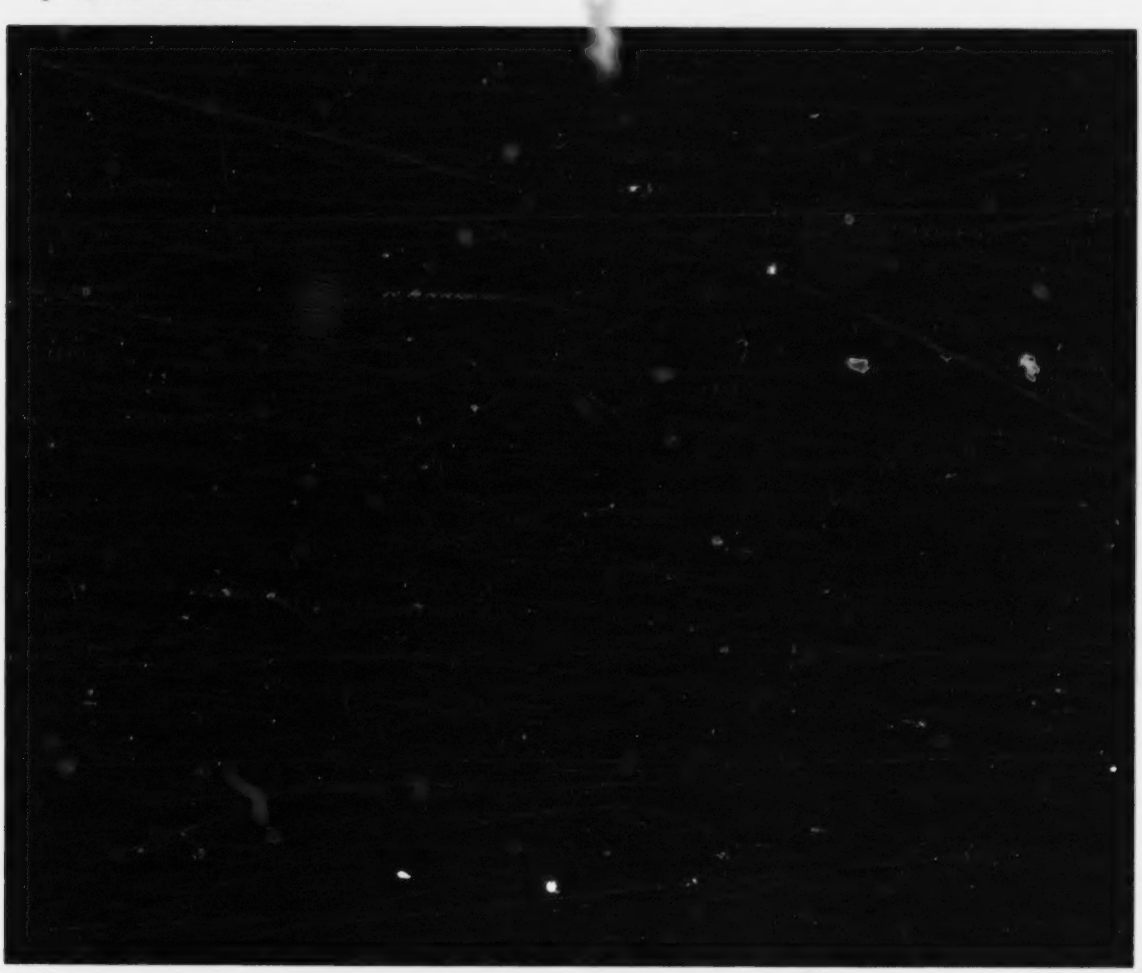
Table 13 presents the distributions of a number of variables for the group of 2485 responding teachers, broken out by gender. Clearly, the fact that women constitute a substantially larger proportion of younger teachers and teachers with less seniority seems to promise that the proportion of female physics teachers should rise steadily over time, although the possible effect of different career patterns (e.g., greater attrition in middle years or earlier retirement) could work to alter the rate of increase.

Table 13 reiterates the rather large salary differential (approximately 20%) between male and female physics teachers, which had been briefly mentioned in an earlier section. However, the just-mentioned difference in seniority levels, reflecting the greater gender imbalance among physics teaches in earlier decades, accounts for about half of the salary differential. Virtually all the rest can be accounted for by the disproportionate concentration of women in Catholic schools (also shown in Table 13), where salaries tend to be substantially lower, and by the curious concentration of women teachers in the low-waged regions of the South. Another part of the explanation for the salary difference may be found in the smaller proportion of female physics teachers with administrative titles in addition to their teaching appointments.

Another finding on earnings that seems worth noting is the relatively moderate difference between women and men in the percentage of household income provided by the respondents' salary. This undoubtedly reflects not only the contrast in salaries between male and female physics teachers just discussed, but also, given the larger differentials that prevail in the overall economy, the differences in occupations and salaries of the teachers' spouses. It suggests that, at least in physics teaching, men and women are on similar footing in terms of reliance on their own earning power.

Other reflections of the traditonal mechanisms that worked to discourage women from entering physics or physics teaching can be seen in comparison of

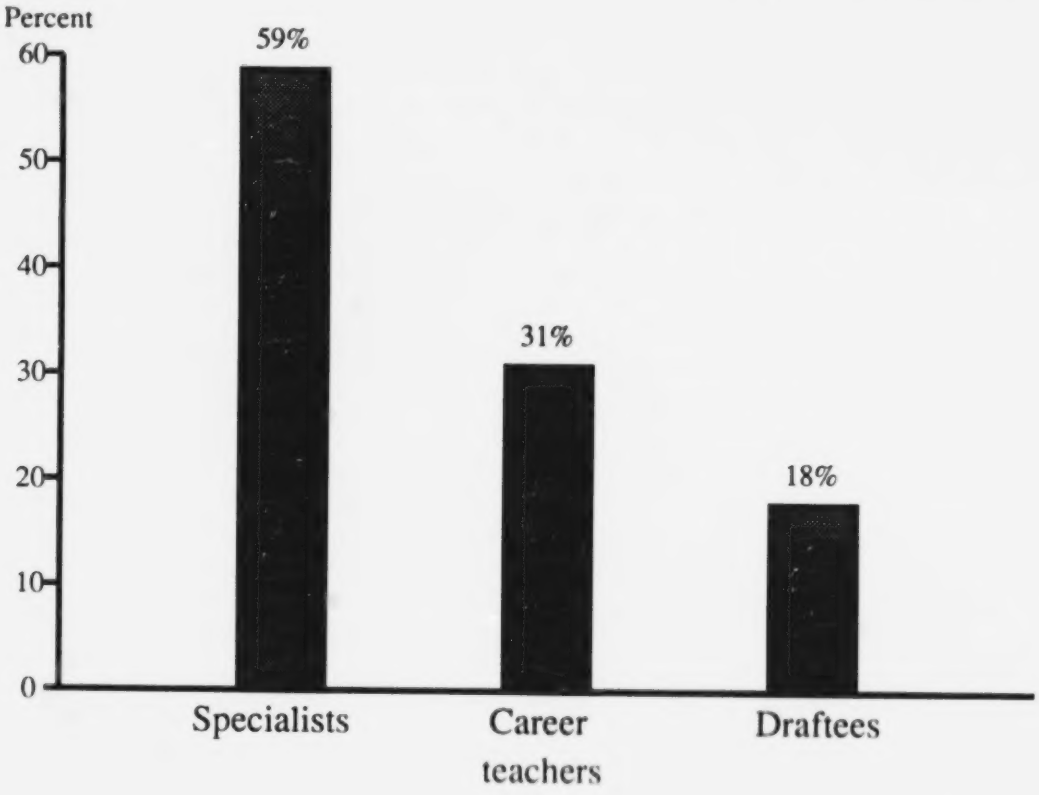
background and training characteristics across gender lines. Women physics teachers are about half as likely as their male counterparts to have earned a degree in physics or to have had physics-related work experience. They are also half as likely to have begun their teaching career with physics as their specialty. Fully half of them, as against only about a quarter of their male colleagues, meet the criteria for having been "drafted" into teaching physics that were referred to earlier in this report. It is small wonder then that three times as many female as male teachers find the fact that physics is not their primary area to be a serious problem in their work.



SPECIALIZATION IN PHYSICS TEACHING

Focusing in more closely on the specialization measure, which, it will be remembered, depends equally on initial training and subsequent physics teaching experience, we find the expected large differences in knowledge and confidence, but surprisingly few differences in approaches to or attitudes about physics teaching. As illustrated in Figure 6, well over half of the "specialists" regard themselves as "extremely well prepared" in basic physics knowledge, while only about a third of the "career" physics teachers, who learned much of their physics "on the job," and fewer than one in five of the "draftees," could say the same.

FIGURE 6. PERCENTAGE OF TEACHERS REGARDING THEMSELVES AS EXTREMELY WELL PREPARED IN BASIC PHYSICS KNOWLEDGE



Among the draftees, there are sizable differences in the degree to which respondents feel secure with their basic physics preparation, depending on the field of primary specialty. Teachers with a concentration in freshmen-level physical science, along with the few specializing in high-school earth and space science, feel most confident about their physics background, followed in order by math teachers, chemistry teachers and biology teachers. (However, it is also worth noting that only 4% of the draftees put themselves at the extreme of being "not sufficiently prepared" in basic physics. Similarly, only 13% reported that the fact that physics was not their primary specialty constituted a serious problem in their teaching.) There is a tendency for the physics "specialists" to have more of their teaching load concentrated in physics, and to teach more of the advanced courses, than the teachers with less formal physics training. However, the latter finding may also result in part from the fact that the specialists are more heavily concentrated in the larger schools, where larger enrollments permit more advanced courses to be offered.

It follows from the definition of the categories that the specialist group has taken far more college-level courses in physics than either of the other two groups. What is especially interesting, however, is that the difference between the group of "career" physics teachers and the group of "draftees" is rather small. This suggests that the differences found between these two groups in the sense of preparation and the degree to which teaching outside one's specialty area is viewed as a problem, is probably almost

entirely accounted for by the difference in years of physics teaching experience. It is "on the job" training, rather than formal education, which, while not bringing the career teachers up to the preparation level of the formally trained specialists, seems to have made a substantial difference in the degree of confidence in physics knowledge relative to teachers who are only infrequently called upon to teach physics. However, it should be noted that the National Science Foundation has recently resumed funding local summer institutes specifically geared toward high school teachers who regularly teach physics but have never earned a degree in the field. These initiatives provide an innovative way to upgrade the formal training of "career" teachers. At the same time, they will also serve to widen the gap between "career" teachers and "draftees," who are largely ineligible for such programs precisely because they do not regularly teach physics. Some of these institutes are quite extensive—for example, one, in upstate New York, spans several weeks over two consecutive summers and a number of meetings during the intervening year, and provides participants with graduate credit as well as stipends.

Perhaps the most interesting findings that emerge from the comparison of teachers at these three levels of specialization as defined here are those that show little or no contrast between the three groups. There seems to be little difference in the degree of influence teachers in the three categories report having over the type of courses offered, the material they cover in their classes, or the textbooks used. Teachers in the three categories appear to have no significant differences in the objectives they pursue in physics teaching—teachers

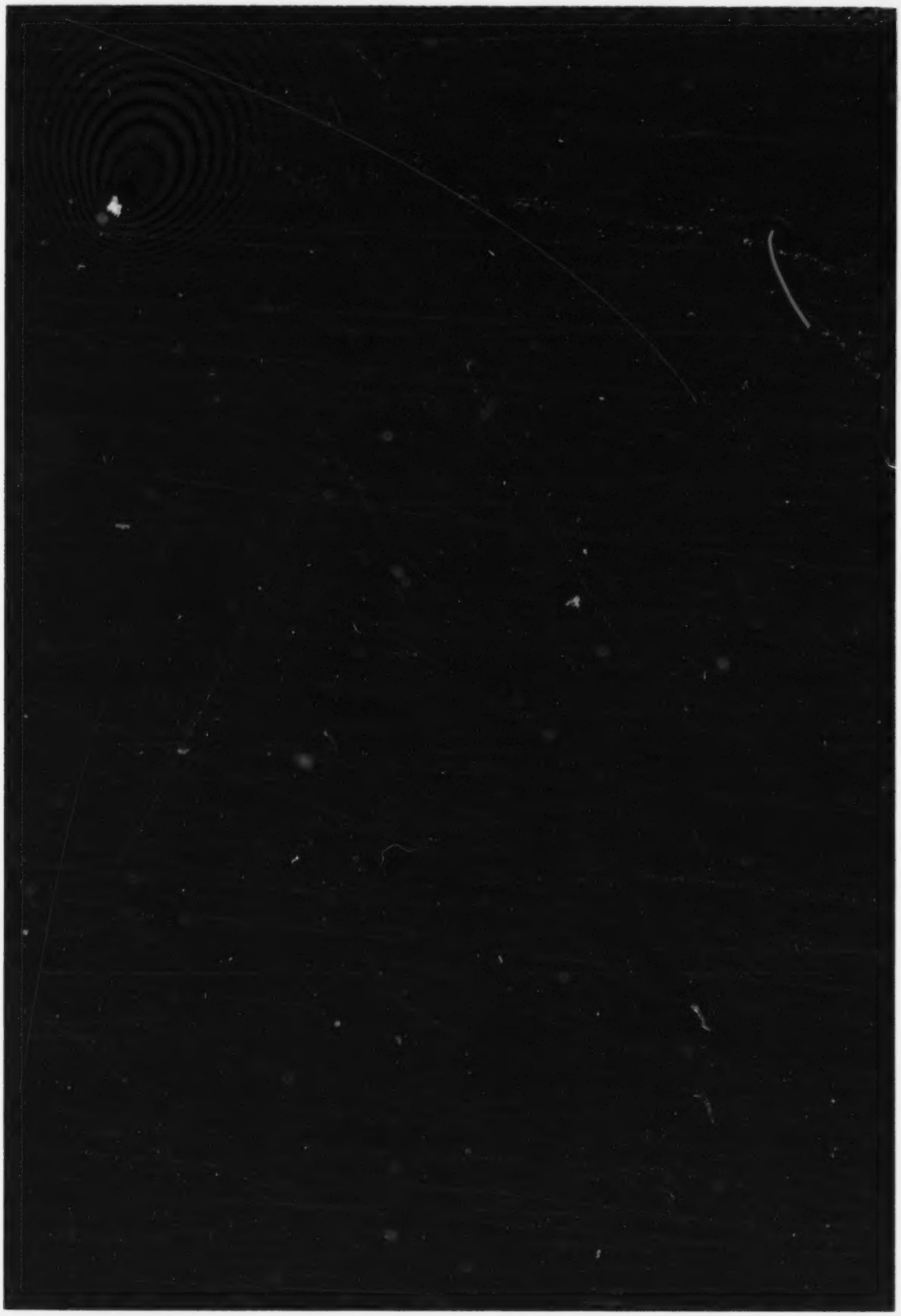
who have formal training in physics and who have devoted their entire career to teaching it do not rank such objectives as "motivating students to continue physics studies," "preparing students for advanced placement tests," or "covering the material necessary to prepare students for further coursework in physics" any higher than teachers from either of the other two groups. There is similarly no significant difference in overall levels of career satisfaction among the three groups. Finally, "draftees" seem to be more highly concentrated in schools located in the south, but there was no significant difference in the distribution of the three types of teachers in schools with varying concentrations of minority-group students.

AGE AND SENIORITY

In addition to concerns about the training and experience of high school physics teachers and about the gender imbalance among the ranks of teachers, a good deal of attention has been given to fears over the possible aging of the teacher corps. Such concern is relevant not merely to the general issue of aging (given a median age for teachers of 41 and an average of 15 years already in teaching), and its implications for replacement and regeneration of this group of teachers, but also to the issue of whether differences between older and younger teachers will slowly lead to substantial changes in the overall characteristics of the teacher corps.

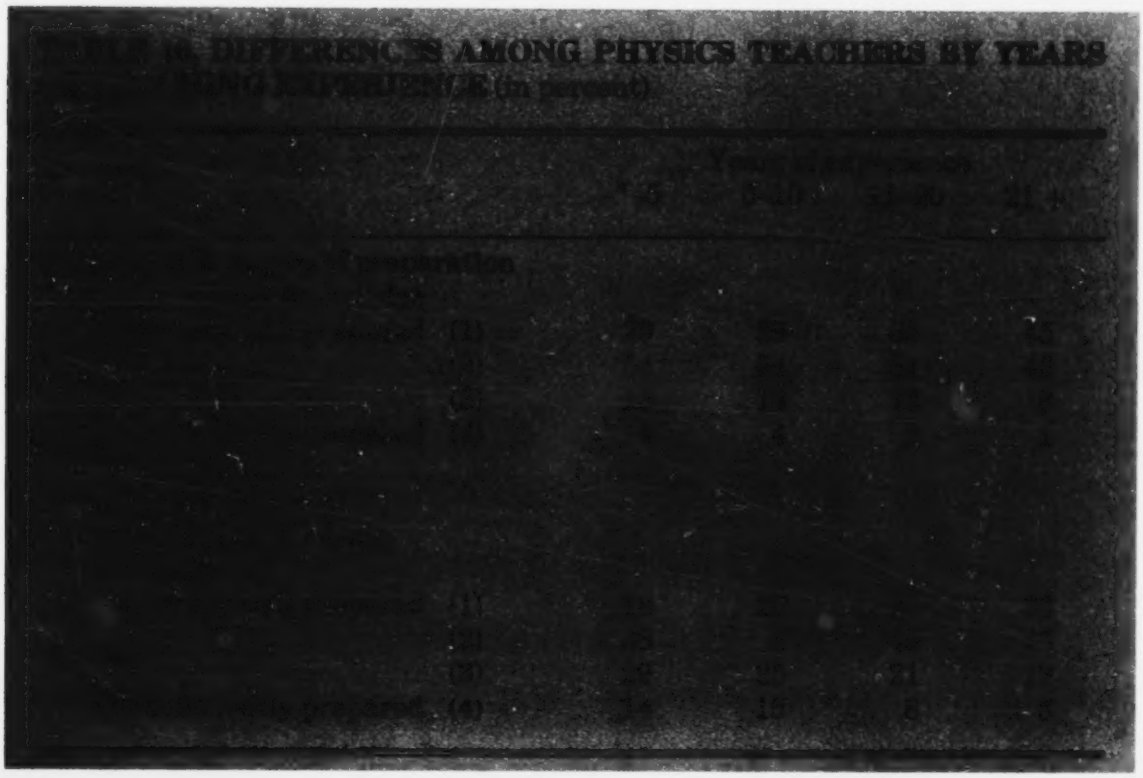
In fact, we have already looked at one difference between younger and older teachers that seems to have positive implications—the fact that there are three times as many women among teachers with less than ten years experience as there are among teachers with 20 or more years of teaching suggests that the gender imbalance discussed earlier should, other things being equal, diminish with the passage of time. Other contrasts between younger and older teachers, however, suggest that there are other forces at work that carry less positive implications. Thus, as illustrated in Table 15, a much larger proportion of the newer recruits plan to leave teaching prior to retirement—it appears that the more seniority a teacher has, the more likely he or she is to plan to hold on until retirement. [However, it should also be noted that it is only among teachers with five or fewer years experience that the proportion actively pursuing a career change rises to even one-in-eight. This accords well with recent indications (Evangelauf, 1987) that, for teachers of all types, by far the highest rate of attrition takes place during the initial years.]

A number of other differences between older and younger teachers appear to be nothing more than artifacts of increasing experience and seniority, and to bode no major changes as recently entering cohorts age and their more senior colleagues retire. Thus, results in Table 15 showing that younger teachers report less influence over the type of physics courses offered at their school and over the choice of physics texts in their courses, feel more isolated from other high school teachers, are able to find slightly fewer sources of professional support, and are less likely to have earned a graduate degree to this point, could potentially imply long-term changes in the corps of physics teachers, but are much more likely to be changes that modulate like waves over the course of each individual career, leaving the overall contours of the group unchanged. (The only way to definitively determine the extent to which this is true would be to conduct a longitudinal survey, looking at individual teachers at a number of points along the course of their career.)



But there are other differences that may also reflect real and permanent changes in cohort characteristics. Teachers with 20 years or more experience who have earned a graduate degree are almost twice as likely as their younger colleagues with graduate degrees to have earned that degree in physics. This finding may have something to do with changing patterns of teacher education—the group with 20 or more years teaching experience are somewhat more likely than newer teachers to have earned their bachelors degree in education, and then have gone on to a masters in a specialty subject area, while more recent entrants into the teaching ranks appear to have more often majored in specialty areas as undergraduates, and then to have pursued (or currently be in the process of pursuing) graduate degrees in education. In part, this may be a product of the "disrepute" into which the undergraduate education degree has fallen in recent years. In the most extreme case, proposals have surfaced in the past few years from such quarters as the Carnegie Corporation of New York, one national association of education school deans, and a City University of New York task force on teacher education, to abolish altogether the practice of granting undergraduate degrees in education (*New York Times*, 10/5/87:B-1). It is also possible that the changing academic degree profile may reflect the later timing of the younger cohorts' decisions to make teaching their career.

Finally, the overall differences in the teacher cohorts' levels of training may also signal a more general loosening of requirements for physics teachers in the face of an increasing shortage of qualified candidates. As one recent newspaper article (*New York Times*, 4/12/88:A-21) notes, while on the one hand almost all states have in recent years instituted formal competency testing for entering teachers, they have on the other hand relaxed certification requirements in fields with shortages, allowing "emergency" certification in many areas for teachers with only minimal backgrounds. To the extent that such a loosen-



ing of requirements has occurred, the finding that older teachers report somewhat higher levels of confidence in their basic physics training may mirror a real and continuing difference in levels of preparation, rather than merely reflecting the confidence that comes from years of experience.

Another finding that emerges in Tables 15 and 16 is that older teachers seem to be somewhat more "laboratory-oriented," devoting slightly more class time to labs and rating themselves as better prepared in techniques for teaching labs (which may relate to the prevalence of experience with NSF-sponsored summer science institutes during the 1960s and early 1970s). Another contrast worth noting is that the newest group of teachers (those with fewer than 5 years experience) are much more likely to have had another career (but not physics-related work experience) prior to entering teaching. All in all, for those who are most concerned about the level of qualifications and physics training, the apparent aging of the teacher corps and the differences that stand out between the younger and older teachers do not seem to offer much encouragement.

Finally, over 700 of the teachers added their own handwritten comments in the space provided for that purpose at the end of the questionnaire. While some respondents wrote only a line or two, most went to substantial efforts, often writing a page or more, with a few adding typewritten letters or additional pages to allow more room. We opened each section above with an excerpt from one of these longer commentaries, hoping to communicate a flavor of the strength with which many of the feelings about the topics addressed in those sections were imbued. It is impossible to give more than an impressionistic sense of the overall content of these comments here, although the body of all these responses constitutes a resource that can, through further analysis, yield the kind of insight and understanding that the quantitative analysis of the rest of the questionnaire cannot provide. However, there were a number of themes that cropped up repeatedly in these comments, and it seems appropriate to end our discussion of the findings on teachers and their experiences with a brief outline of these. Among the most common threads were:

1. a sense of satisfaction and attachment to physics as a discipline—many teachers mentioned a love of the subject matter they taught, and a feeling of excitement and gratification at being able to pass it on to their students;
2. a feeling of isolation, especially from other physics teachers and physics professionals—teachers felt a lack of emotional support and camaraderie, as well as missing the chance to exchange ideas and techniques for use in the classroom;
3. as far as the latter was concerned, many teachers bemoaned the lack of forums and institutes where they could polish their skills and fill in gaps in their physics knowledge, as well as keep up with new developments in the field. Older teachers who had attended NSF-sponsored summer institutes in years past were especially emphatic about the importance these institutes had held for them, both in gaining new insights into physics and physics instruction, and in general for "recharging their batteries";
4. a number of teachers expressed gratitude for an older teacher in their school or district who served as mentor and resource—some said that if it hadn't been for the help and influence of these senior colleagues, they would have quit teaching, or at least quit teaching physics, in their first few years;

5. there was widespread frustration with low pay and lack of recognition and support from school and district administrators. Teachers complained especially about the time pressure—the lack of recognition that they needed extra time, and relief from class assignments, to prepare laboratories, the distraction of peripheral tasks such as lunchroom duty, hall monitoring, study hall assignments, and so forth;

6. bitter complaints from many of the teachers drafted from other specialities over how they had been forced into taking the physics assignment against their will. Some of these teachers reported that being put into the position of teaching material in which they were not well-prepared was offensive to their sense of professionalism—a number said it would drive them out of teaching altogether. Others seemed determined to persist, but expressed despair over ever getting proper training;

7. finally, a number of teachers commented on the questionnaire itself. A few condemned it as a waste of time, or predicted that it would merely be used by the "physics-teaching establishment" to reinforce their distorted and elitist preconceptions. Some made practical suggestions for changes or additions, pointing out instances of poorly worded questions or topics that had been overlooked. But many simply expressed gratitude that "someone was finally willing to listen" to the experience of the teachers in the trenches, regardless of their official professional credentials.

IX. PRELIMINARY FINDINGS ON PHYSICS COURSES

"My course was basically science for non-science types; none of my students expect ever again to study physics, and a goal of the course was to teach them not to be intimidated by formulae and scientific language, but to jump in and learn their way around."

—A Florida teacher

The 2485 respondents to the survey taught a total of 5044 physics classes and had 3164 preparations (separate courses) during the Spring 1987 term. On a weighted basis, this works out to an average of 1.9 physics classes and 1.2 physics preparations per teacher. The distribution of assignments among teachers and data on the amount of lab time and homework assigned for each type of course are presented in Table 17. Data on the textbooks that were most widely used in each type of course, and the quality ratings each of these received by the teachers, are presented in Table 18. In general, teachers seemed to be quite satisfied with the textbooks they used—ratings were relatively high across the board, and when asked whether they found textbook quality to be a problem in their teaching, 65% said no, and only 5% rated it as a serious problem. On the whole, texts used mainly in accelerated or advanced courses, where more sophisticated material can be handled, received better ratings than texts used primarily in introductory courses. It is also important to bear in mind that texts are normally geared to a specific level of instruction, and that low ratings may result from the misuse of a book in a given course, as well as from its actual intrinsic merit.

USE AND RATINGS

		Mean quality rating*
	26	3.7
	38	3.6
	7	3.9
	6	3.6
	5	3.6
	28	3.7
	24	3.6
	7	4.3**
	7	3.3**
	6	3.8**
	21	4.3
	20	4.5
	9	4.2**
	8	4.3**
	7	4.3**
Second Year:		
1. Physics (Giancoli)	31	4.1**
2. Modern Physics (Williams *et al.*)	12	4.4**
3. University Physics (Sears *et al.*)	11	3.6**
4. Fundamentals of Physics (Halliday and Resnick)	10	4.4**
5. College Physics (Sears *et al.*)	10	4.8**
Physics for Non-science Students:		
1. Physics: Principles and Problems	28	3.3
2. [illegible]	27	4.5
3. [illegible]	12	2.8**
4. [illegible]	8	4.0**
5. [illegible] and Methods (Taffel)	4	2.8**

*N.B. The ranking scale for this measure reflects only an ordinal ranking. The mean should be interpreted as only an approximate guide to the relative distribution of teachers' evaluations of textbook quality. Small discrepancies are not likely to reflect meaningful differences in ratings.

**Ratings may be unreliable due to the small number of cases.

Finally, given the preponderance of regular first-year physics courses, we asked teachers to go into more detail concerning what topics they covered and how much class time was allocated to each. In terms of seven broad areas, teachers with first-year physics classes reported spending an average of 35% of the time on topics in mechanics, 18% on optics and waves, 16% on electricity and magnetism, 12% on heat and kinetic energy, 8% on measurement and math skills, 7% on topics in modern physics, and 4% on a broad array of other issues.

For comparison purposes, Table 19 provides a further breakdown of these areas into specific subtopics, and indicates the proportion of teachers covering each of the latter in their regular first-year classes. Pfeiffenberger and Wheeler (1984) conducted a study of high school physics courses in 1983, which included an item on course content that was identical to the one used here, with the exception that their list did not include "measurement and math skills" or "other topics" as categories. Even taking this into account, the responses they received were very close to our own—they reported a mean of 36% of course time devoted to mechanics, 20% each to electricity/magnetism and optics/waves, 13% to heat and kinetic energy, and 9% to modern physics. It is also worth noting that their findings for the mean and mediam number of students per school enrolled in first-year physics—32.7 and 17.5, respectively—agree closely with our own corresponding figures of 30 and 20.

X. PHYSICS EDUCATION OUTSIDE THE PUBLIC SCHOOLS

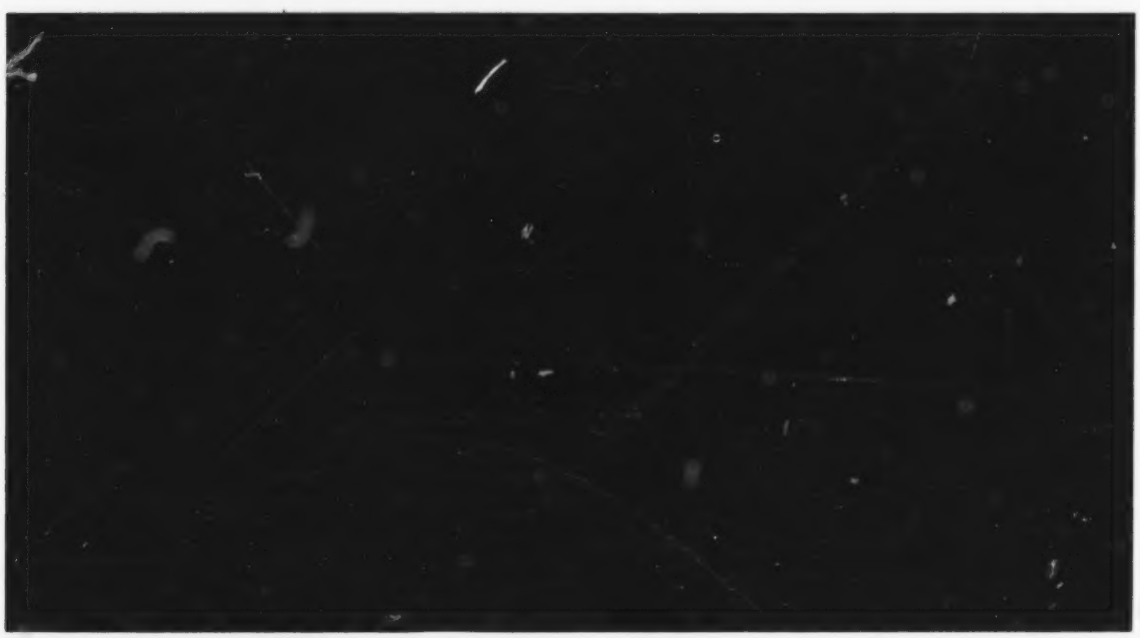
"I was an...Assistant Principal and Science Supervisor [in a major urban public school system]...for 17 years. Present school is very different from my previous experience. Small, all girls parochial high school. Students must pass an entrance exam for admission. Intelligent, highly motivated, disciplined—a pleasure to teach."

—Parochial school teacher from an East Coast city

In Section IV above, a number of findings were discussed for public schools only. Given the strong association between school size and type of religious affiliation, this was done in order to keep the textual and tabular presentation of the data straightforward, minimizing control variables and interaction effects. It was felt that, given the overwhelming predominance of students in public schools, this could be done without severely distorting the picture of secondary school physics education in this country. In this section, we will turn back to differences between different types of schools, to see whether the contrasts suggest alternative approaches to physics education that analysis of the more homogeneous public sector might not reveal.

The original school list from which the sample was drawn classified schools into three categories by type of affiliation—public, Catholic, and private. As we noted earlier, the category of private schools seems to be furthest from public schools in terms of structural characteristics, and to exhibit the greatest internal heterogeneity of the three types. Unfortunately, neither the questionnaire nor the data elicited by QED contained items that would serve to further delineate school affiliation within the private school category, thus turning it into a kind of catch-all for non-public and non-Catholic schools. However, given that the school name seemed to reliably indicate the presence of religious affiliation in many cases, we made an attempt to classify private schools still further on that basis. Telephone contact was made with the school in ambiguous cases, and was used to check the accuracy of the classification in a small proportion of seemingly unambiguous cases as well. The results of this effort are presented in Table 20.

In general, the "mainstream Protestant" affiliation included high schools (primarily Lutheran and Episcopalian schools) which have tried to mirror, albeit on a smaller scale, the uniform approach and consistent character of the Catholic education system in this country. Given this conclusion and the small number of Protestant-affiliated schools, it was decided to classify them with the Catholic



schools as "mainstream religious high schools." Similarly, in light of the fact that most of the Jewish schools were Orthodox in their religious orientation, it was decided to combine these schools with the Fundamentalist Christian schools (Bible Schools) to create a category of "fundamentalist religious schools." Twelve schools could not be easily classified into these categories, and so were excluded from the analysis.

Following this reclassification, the two subgroups that emerge from the former private school category exhibit a number of structural similarities but seem to stand on opposite ends of the academic spectrum, at least as far as physics instruction is concerned. Thus both the fundamentalist religious schools and the private schools without religious affiliation are substantially smaller than either the public schools or the schools affiliated with "mainstream" religious groupings. Similarly, while almost two-thirds of the public schools and over three-fourths of the mainstream religious schools focus on only the high school grades, only a small fraction of non-religiously affiliated and fundamentalist schools do likewise. Yet, despite these similarities, a substantial proportion of the private schools with no religious affiliation offer physics every year, while the percentage for fundamentalist schools is much smaller, even when school size is held constant. Overall, as shown in Table 21, the apparent lower priority placed on physics instruction at many fundamentalist schools, coupled with the fact that these

schools are especially concentrated among the tiniest schools in the sample, adds up to a situation in which over 60% of these schools do not offer physics at all, as against 31% of the secular private schools, and an even smaller proportion of the larger "mainstream religious" schools and public schools.

Even comparing the relatively "elite" group of fundamentalist religious schools which did offer physics in 1987 to schools from the other categories offering physics (cases which are far more representative of their respective groups), we find that differences abound. Once again, as Table 22 makes clear, the fundamentalist religious schools and the secular private schools seem to stand on opposite ends of the spectrum. Despite their much smaller size, the latter schools offer, on average, a slightly higher number of physics classes than do the public or mainstream religious schools, while virtually all of the fundamentalist schools that do have physics offer only one class in the subject. Similarly, despite their size, a substantially higher proportion of secular private schools with physics have multiple physics teachers than is the case for public and mainstream religious schools, while, with only one exception, no fundamentalist school in our sample has more than one physics teacher. Furthermore, while none of the fundamentalist schools offer courses beyond introductory physics, the proportion of the secular private schools with physics programs which offer second-year or advanced placement courses in physics is twice as high as the proportion of public or mainstream religious schools offering those advanced courses.

Not only are the secular private schools and the fundamentalist schools widely divergent in terms of the extent and structure of their physics programs, they are also different in terms of the personnel staffing those programs. About half of the faculty at secular private schools, as against just over a third of the public and mainstream religious school teachers, fit into our "specialist" category as defined in Section V above. The comparable figure for fundamentalist schools is one-sixth, and well over half the teachers at these schools fall into the "draftee" category delineated earlier.

A similar finding holds true for academic background—teachers from the secular private schools have taken slightly more college physics courses than the average, while teachers from the fundamentalist schools have substantially fewer. Moreover, more than a third of the former group have degrees in physics, as against just over a fourth of the public and mainstream religious teachers, and about a sixth of the fundamentalist school teachers. In terms of general academic attainment, a larger proportion of those teaching physics in the secular private schools have earned a Ph.D. than is the case for teachers at the other types of schools. Non-religious private school teachers also have substantially more money per physics class available to them for supplies and equipment, and, again despite lower overall enrollments, make more types of physics-related extracurricular activities available to their students than do teachers at other schools.

The picture of physics instruction that thus emerges from the findings shows some relatively sharp contrasts. On one extreme, the small secular private schools seem to form an elite in terms of their commitment to high-quality physics instruction, and in terms of the personnel and budgetary resources they provide for that purpose. In spite of their limited size, a relatively broad physics

curriculum is offered, and a substantially greater proportion of students are enrolled in advanced physics courses. Finally, those hired to teach these courses tend to be better trained, better equipped, and find fewer serious problems hampering their teaching efforts. On the other hand, many fundamentalist religious schools do not offer physics, and even where it is offered, only the basic introductory course is available. More often than not, the course is given by a teacher who has only a minimal background in physics.

In between these extremes stand the much larger and more numerous mainstream religious and public institutions. Given their large enrollments, it is perhaps not surprising that 90% of the schools in both categories offer physics at least every other year. But, once size is controlled for, it turns out that, like the secular private academies, the parochial schools also seem to place more stress on physics education than does the group of public schools, taken as a whole. For example, a higher proportion of mainstream religious schools than public schools of comparable size offer advanced physics in addition to the basic introductory course. And, most significantly, public schools with physics enroll a substantially smaller average proportion of their students in physics than do schools with physics in the other three categories. While almost one half of the secular private school graduates have taken physics, along with a third of the parochial school graduates and a similar fraction of the minority of fundamentalist schools which offer courses in the subject, the comparable proportion for public school graduates is less than one in five. Put another way, the non-public schools, taken together, have 10% of the nation's high school seniors, but 16% of the country's high school physics enrollments. [This relationship appears to be stable over time—AIP (1964:2) reported an almost identical fraction of the nation's physics enrollments in non-public schools twenty-five years earlier.] Of the 82 schools in our sample where physics was offered and where less than 5% of the senior class graduates having taken a course in the subject, all but one are public schools. Furthermore, it is worth noting that, among this group, inner city schools with predominantly minority enrollments are heavily over-represented.

Part of the explanation for this finding undoubtedly lies in the relative selectivity, and self-selection of students, among the different types of schools. Schools in all three of the non-public categories charge tuition, while public schools, of course, are free. This in itself may give rise to a situation where students in private and parochial schools, and especially those in the secular school group where tuition rates are often highest, tend to be drawn from higher socio-economic levels than public school students, on average. In this regard, it is worth noting that teachers from the three non-public categories report that these schools send the overwhelming majority of their students on to college, while public school teachers indicate that the proportion in their schools averages under half. (The 1980 High School and Beyond study reported identical figures for public school and slightly lower ones for private schools.) Put another way, 85% of the non-public schools, but only 18% of the public schools, in the sample sent at least 70% of their graduates on to college. And, as noted earlier, the proportion of students going on to college is one of the most powerful covariates of the percentage of students enrolling in physics among schools of all types.

There are other indications that private and parochial schools lay heavier stress on academics, and especially science, in their curricula than public schools do. Despite the recent movement towards more rigorous graduation requirements in public schools in many states, public school teachers in our sample still reported science requirements that were significantly below the average for schools in the other three categories. Thus, while about 40% of the non-public schools require 3 or 4 years of science, only 20% of the public schools do likewise. It is likely that this is at least partly related to the relative flexibility that the administrations of non-public schools and school systems have in setting graduation requirements and academic policy in general, relative to the more constrained quasi-legislative process to which public schools must respond on a district-by-district and state-by-state level. In similar fashion, non-public schools can be somewhat selective in their choice of students and academic orientation, while public schools are committed to accepting all "comers" and must gear minimum graduation requirements accordingly. Finally, public schools are subject to an involved budgetary process, which, while at times providing more funding, may limit their flexibility in hiring personnel and allocating funds to subject areas which may be in need of special emphasis.

XI. CONCLUSION

"I am appalled at the lack of science education [in the United States] just in terms of the number of years that a subject is taken. How can physics be taught in a year to any depth? Worse is the fact that so many U.S. students pass through high school and into the world with no idea of physics."

—A teacher trained in England

The discussion in the previous section suggests that there are three primary sets of factors which, through mutual reinforcement, combine to shape the character and delineate the breadth of high school physics programs. The first of these can be summed up as the commitment of the school administration to quality science instruction, reflected in policies regarding number of years of science required for graduation, the academic rigor of the curriculum as a whole (especially its orientation towards preparing students for further, post-secondary schooling), and the background and training of the faculty hired to translate this orientation into education. The second set of factors, also all intertwined with each other, revolves about the character of the school—its size, its regional location, and its setting in a metropolitan or rural area. The third set of factors involve the demographic character of the student body—especially its socio-economic level and racial and ethnic composition. In general, each of these sets of factors has only a moderate effect when taken alone, but they appear to have a powerful influence when operating in tandem.

Smaller secondary schools which make a strong commitment to physics and science education in general appear to be able to maintain a robust and high quality program in the subject—this can best be seen among the parochial and especially the non-religiously affiliated private schools. But, for the 90% of students enrolled in the public schools, the character of the physics program—in terms of the breadth and depth of the curriculum and the background and training of the teachers—seems very sensitive to the magnitude of enrollment in the subject. Small school size, low graduation requirements in science, students who have received poor backgrounds in science and mathematics in earlier grades and who have low educational aspirations, all combine to keep absolute enrollment levels in physics low. Small enrollments, in turn limit the variety of classes which can be offered, usually restricting the physics curriculum to the basic introductory class. They also limit the number of classes in all but the biggest schools, forcing the teacher to accept assignments in other areas to fill out his or her roster or, perhaps more often, causing a teacher from another specialty to be "drafted" into teaching physics, frequently with little background in and enthusiasm for the subject.

Low enrollments can thus be pictured as operating in a way that serves to set up a pair of intertwined vicious circles. The scarcity of schools where a teacher can devote herself or himself to physics probably works to discourage some prospective teachers from choosing the field as their area of specialization. This situation, combined with the widely recognized fact that high school teaching is one of the least remunerative and prestigious alternatives facing college physics majors upon graduation, limits the number of physics specialists going into high school teaching. The combination of these two factors only serves to further increase the number of schools which must "draft" teachers from other specialties to teach the one or two physics courses they are able to offer. Second, the prospect of taking physics from an unenthusiastic and undertrained "draftee," combined with the course's reputation as an academically-difficult subject, probably discourages many students from taking it, further reducing enrollments.

While the above discussion lays out the effects of low enrollments—effects which may serve to reinforce it—the primary mechanism that sets physics enroll-

ments at low levels to begin with and functions to keep them there emerges as an unintended byproduct of two long-standing educational practices. First, flowing from the tradition in the United States of universal education, which in recent years has extended to encouraging a high proportion of students to stay in high school through graduation, minimum graduation requirements have been set low. In science, this translates into a requirement of one or two years in the overwhelming majority of states and districts. Even with the recent emphasis on upgrading requirements, only a handful of states require as many as three years of science from grades nine to twelve, and virtually no schools require four years.

On the other hand, physics has traditionally been offered as the last course in the sequence: physical science, biology, chemistry, physics. In fewer than 5% of the public schools in our sample did teachers report that physics was normally offered prior to chemistry. The rationale for the standard sequence was that physics, as it was traditionally taught, required more sophisticated mathematics than the other courses. Leaving it to last allowed students taking it to gain the broadest background in math prior to enrolling. However, the conjunction of these two practices meant that, in contrast to biology—and even chemistry in schools requiring three years of science—physics became, for all intents and purposes, an elective course for those students who follow the standard sequencing. Given its "hard" reputation, and the fact that many advanced math courses are also treated in essence as electives, it is small wonder that physics is shunned by the vast majority of students, with the effects detailed above.

Whether or not it is "proper" that only a small fraction of high school students in the United States completes a course in physics prior to graduation is an issue that has already seen wide discussion, and goes to the heart of disputes over basic academic policy and the place of science education in this country. Many school districts have chosen the option of concentrating their best science students in special magnet schools, where personnel and budgetary resources can be concentrated and instruction of the highest quality pursued. As Wilson and Ingoldsby (1983:53) point out, these schools "...provide some illustration of what can be done with the best students in a controlled environment that emphasizes science and attenuates much of the distractions faced by science students at other schools." Some states, notably North Carolina and Maryland, have gone so far as to set up a single residential science high school for the state, which offers "free room, board and advanced study to the state's top [science] students." (*Washington Post*, 8/22/87:D-1) The resources at these schools can be considerable—Oleck (1987:24) reports that in North Carolina's School of Science and Mathematics, "The physics department alone boasts Ph.D.'s in astro-, bio-, solid-state and theoretical physics." However, concern has been voiced in other quarters over the effects such an approach might have for the level of science instruction in the high schools and among the students who are not so favored. A recent study of the National Science Foundation's proper role in pre-college science education commissioned by the U.S. Congress , concluded that "...NSF's mandate at the K-12 level should be to enlarge the pool of science learners rather than to offer opportunities for the most able students to embark on a scientific career." (Rothman,1987:7)

It is not our intention to add another voice to the debate here. But it is appropriate to recognize that, regardless of whether it is felt the present approach is the optimal one or not, or even whether alternative policies are possible to put in practice, the current situation has implications not only for the number of students taking physics, but also for the level of instruction experienced by those who do enroll. As we have endeavored to show in the previous paragraphs, low enrollments effect the variety of courses and the qualifications of the instructors available to those students whose interest and background propel them to sign up. Our findings have reinforced the commonsense notion that it is precisely those schools which enroll a high proportion of their students in introductory physics which are more likely to be able to hire physics specialists and to offer advanced placement and second year courses in the field.

It would be instructive here to return to the experience of other countries. As noted in the Second International Science Study Report, *Science Achievement in Seventeen Countries: A Preliminary Report,* most other countries retain a much smaller proportion of their students in secondary school. But those that are retained face much more rigorous requirements—science requirements typically extend across all years of the grades equivalent to our high school, and physics is one of the courses required of all the students. In fact, in some countries a high proportion of students take two years of physics, while in others students must take a number of years of combined science courses prior to graduation, courses which include heavy doses of physics (see also Klein and Rutherford, 1985:149).

The upshot of all this is that, in all but one of the countries surveyed, a larger proportion of all high school age youth is exposed to a second-year course in physics than the 1% who are currently so exposed in the U.S. (It should be noted that their target population of 28,722 students taking advanced placement or second-year physics in the U.S. corresponds quite closely to our own estimate of 25,200 from Table 1. For comparison purposes, the Educational Testing Service reports that a total of 12,700 students sat for all versions of the 1987 advanced placement test in physics, and Pfeiffenberger and Wheeler (1984:574) included an estimate from the College Board indicating that the number of students taking the SAT Physics Achievement Test has remained in the 14,000–18,000 range throughout the previous eleven years.) Even more startling, performance tests administered to these advanced and second year physics students as part of the study resulted in scores that placed U.S. students, the "cream of the crop" in this country's high school physics programs, near the bottom of the international ladder in terms of physics knowledge. (One possible caveat is that A.P. physics students in the U.S. may be taking physics for the first time, while in some of the countries covered, the target population was restricted to students in their final year of secondary school who were enrolled in a second-year physics course.) The study's authors acknowledged problems with the comparability and use of some questions for students in this country. Still, it is striking that almost 90% of the schools in the United States had mean scores lower than the average of physics students in their final year at the poorest performing secondary school in Hong Kong, the country with the best overall scores. The report also notes (IEA,1988:4) that test scores for all sciences, and presumably physics as well, showed greater variability from school to school in the U.S. than was the case in all but four of the

other countries. As Walsh (1988:1237) put it in an article entiled "U.S. Science Students Near Foot of Class" in the journal *Science*, the report showed that, unlike most other industrialized countries, "...the U.S. pattern conformed to that of developing countries where sharp contrasts between elite schools and others are common."

In their discussion, the study's authors stressed the contrast between the highly varying availability of and instructional approach to high school level physics in this country, and the more highly regulated and consistent programs available in most of the other nations surveyed. While confirmation is not possible either in that study or in our own, it would appear to be a plausible hypothesis for further investigation that linkages exist between the breadth of secondary school physics programs (in the sense of proportion of students enrolled) and the depth of those programs, in terms of the sophistication of material taught—and learned. Rather than being competing goals, it would appear that the approach which focuses on promoting science literacy for a wide proportion of students, and the approach that emphasizes high-level instruction for the ablest and most interested students, are actually complimentary strategies for improving physics instruction in our nation's high schools. Further substantiation for this conclusion comes from the Klein and Rutherford study (1985:4) which found that, in contrast to the U.S., Japan, East Germany and the Soviet Union all "...appear to provide a fairly vigorous scientific and technological education to more than 90% of their youngsters while continuing to find and educate students of high talent to carry on the scientific and technological activities of the future. These examples suggest that a scientific elite does not have to be produced at the expense of the rest of the population, nor does the elite have to be sacrificed in order to achieve mass education."

However, it is undoubtedly also true, as the IEA authors take pains to point out, that the factors accounting for the differences in the breadth and level of sophistication of physics programs in various countries are deeply rooted in the nations' educational and social structures. The authors of that study found differences in performance on science comprehension tests that reached back into the junior high and even the elementary grade levels. Preliminary analysis of the High School and Beyond data from U.S. high schools confirms the intimate link between science instruction and the acquisition of skills in related academic fields such as mathematics and even reading. And our own findings suggest that variations in physics instruction are related to structural factors such as the ethnic and socio-economic composition of the student body and the regional and metropolitan setting of the school, as well as to more proximate factors such as funding for equipment and supplies or the background of instructors. Nevertheless, in light of the decentralized character of the U.S. educational system that we noted at the outset of this report, it must be recognized that the major impetus for improvement must come from the state and local level, and ultimately from the ranks of the teachers themselves, for it is at that level that the clearest sense of the promises and potential pitfalls of new initiatives resides.

There is a wealth of information in AIP's High School Physics Teacher Survey even beyond what has been discussed above. Some of that data will form the basis for future reports that will examine particular groups and issues more closely.

There is still a pressing need to understand more clearly why certain schools are able to achieve considerable success in maintaining quality physics programs, while others fall far short of what their resources will permit. And beyond the issue of variation between schools lies the question of how satisfactory is the overall level of physics enrollments in this country's secondary schools, in terms of projected national academic and job market needs. Other, still broader questions are even more political in character, such as whether it is more appropriate to emphasize science literacy among the broad ranks of students who will not end up making physics their career, or whether it is better to concentrate on giving more of a headstart to future professionals. Neither this nor any other study can "answer" such questions, but careful analysis can well serve to provide a solid background and pinpoint the areas in which answers may be sought.

APPENDIX A. SURVEY METHODOLOGY

The initial work leading up to AIP's 1986–87 Survey of Secondary School Teachers of Physics began in 1985. In that year, a series of meetings between AIP staff and representatives of the American Association of Physics Teachers led to the construction of a preliminary survey instrument. Contributions to questionnaire design were also elicited from a number of other sources, including Dr. Iris Weiss, then of Research Triangle Institute. In several instances, items from Dr. Weiss's 1977 Survey of Science and Mathematics Education served as models for items on the AIP questionnaire, in order to facilitate efforts at comparison and replication. The resulting questionnaire was pretested on a sample of over 200 AAPT members early in the following year. Revisions to the survey instrument were made in later 1986 and early 1987, based on the pretest experience and on comments from pretest participants.

At the same time as the pretest results were being processed, the research universe for the nationwide survey was defined, and a sampling procedure was designed by AIP staff, in consultation with staff members from RTI. Our survey universe consisted of 23,161 schools containing a twelfth grade class that were included in the master list of schools maintained by Quality Educational Data, Inc. (QED), an educational data resource firm. Our initial sample was stratified by school type and average grade size and then disproportionately sampled, in order to ensure adequate representation from Catholic schools and large public schools. Proportional stratification by geographic region was also used to ensure sufficient representation from all sections of the nation.

The rationale for stratified sampling derived from the assumption that the biggest schools, while fewer in number than the smaller schools, probably contained the largest number of physics enrollees and the most varied physics curricula. Furthermore, the overall number of Catholic schools was low, and these too tended to be larger than other non-public schools. We therefore randomly sampled 30% of all public schools with an average of more than 500 students per grade, as well as all Catholic schools regardless of size. For the numerically much

larger categories of public schools with an average of fewer than 50 students per grade and private schools with an average of fewer than 10, our sampling proportion was only six percent. All other categories were sampled at an 18% rate (generating a sufficient number of cases in each cell of the sampling frame to permit detailed yet reliable analysis), yielding a total initial sample of 3631 schools (15.67% of the target population), distributed as shown in Table A-1.

As important as the pretesting and the design of the sampling procedure in the ultimate success of the study were the efforts made to ensure cooperation and interest at all levels of the educational administration structure. (Again, valuable help was obtained at this key stage from Dr. Iris Weiss, who shared the experiences from her own prior survey efforts.) In the Fall of 1986, letters were sent to the members of the Council of Chief State School Officers and to all fifty State Science Supervisors, informing them of the goals and the needs of the upcoming study. This was followed by a mailing to all 2100 Superintendents of

the public school districts which contained schools in our sample. In addition, the heads of more than a score of private and parochial school organizations were contacted. In over a dozen cases, special state- or district-level applications were completed to comply with local requirements for conducting educational research. The response at all these levels were overwhelmingly positive and encouraging, and cooperation was ultimately secured in every instance.

In December 1986, a mailing was sent out to the principal of each of the sample schools, inquiring as to whether physics was offered at the school during the current (1986–87) or previous school year, and asking for the names of all faculty teaching physics classes during the current year. Three mail waves yielded usable responses from 2952 principals, or 81.3% of the total. Telephone calls to ascertain the desired information were then made to the remaining 679 schools, yielding 520 usable responses. A further 131 schools on the QED list were found either to have been:

a) schools that did not meet the population definition because they did not go up through the twelfth grade (98);

b) schools that had closed prior to the begi. ning of the 1986–87 academic year (24); or

c) duplicate listings of schools already included in the sample (9).

Removing these 131 schools left an interim sample of 3500 schools. Twenty-two additional schools, while not definitively ruled out of the sample, did not respond to repeated mail and telephone inquiries. In six of these cases, it was ascertained that the school had indeed closed, but the date of closure was not determined. In five cases, mail was returned as undeliverable, and the telephone had been disconnected as well. In three cases, mailed queries were likewise returned, but a phone number was still listed, although repeated calls obtained no response. In the remaining eight cases, mail was not returned, but the telephone was listed as disconnected. Given the lack of mailing address and/or telephone number in the middle of the academic year, we felt safe in assuming that these schools had also closed down, although we could not say with certainty that they had closed prior to the beginning of the 1986–87 academic year.

The rationale for including these twenty-two schools in the sample would be that they would serve as a rough stand-in for currently operating schools that opened between the time that the QED list was drawn up and the point at which our first teacher mailing was sent out. It is, however, unlikely that schools open after the beginning of the academic year, even though financial and other problems may force some schools to close prior to the end of the year. Even if they were to be included in the sample, data available from the original QED listing showed that most of these 22 schools were in the smallest size category (all except one of the 22 had an average of less than fifty students per grade), and the vast majority (19 out of 22) were private academies, mostly affiliated with fundamentalist Christian religious groups.

Moreover, there was a marked pattern to the timing of principal responses to our queries, with principals of schools offering physics tending to respond earlier

than principals of schools without physics. Thus, only 9% of the principals responding to the first mailing reported that their schools did not offer physics in 1986–87, while 17% of those responding to the second wave reported likewise. In the final mail wave, the percentage reporting no physics rose to 28%, and almost one-half (48%) of those who were finally reached by the telephone follow-up did not have physics in 1986–87. Given the size and type distribution of these 22 non-responding schools, and assuming that, if they had finally responded, their physics-offering profile would have most resembled the schools which did not respond until the telephone inquiry, we estimate that, even if all of these schools were in fact open and had a twelfth grade, only about seven of them were likely to have offered physics in 1986–87, and that each of those schools were likely to have had only one physics teacher apiece.

However, in view of the likelihood that these schools were not operating throughout the academic year, and that no new schools had opened after the start of the year, we felt justified in excluding these schools from our sample, leaving a final figure of 3478 schools that were operating in 1986–87 and went up through the twelfth grade. Table A-2 provides the unweighted distribution of these schools by average grade size and by type of affiliation.

Six principals in this group declined to allow their schools to participate in the study, giving us a response rate for schools of 99.8% with no substitution of cases. From the size and affiliation characteristics of the six non-participating schools, we can make a rough estimate that these schools appear likely to have contained no more than four teachers with physics classes, giving us an estimated total "coverage" of all teachers of physics in our sample schools of 99.9%, close enough to 100% to be considered virtually complete. The 3472 responding schools included 2846 which offered classes in physics. The principals at these schools

gave us the names of a total of 3301 teachers who taught physics classes. Following three mail waves and a telephone follow-up, 2485 of these teachers, or just over 75%, completed the twelve-page questionnaire.

Putting aside the issue of response bias for a moment, even if all principals and all teachers had responded to our surveys, our estimates of the characteristics of the population they were chosen to represent would still be subject to sampling error. Most of the findings discussed in this report are presented in the form of simple proportions of schools or teachers (indicating the percentage of the sample, or a subgroup of the sample, falling into a particular category of a given variable). The estimated size of the sampling error of a proportion for a simple random sample varies with the magnitude of the particular proportion in question and the size of the sample or subsample under examination, and is given by the formula,

$$S = \left(\frac{p(1-p)}{n}\right)^{1/2}.$$

For example, if we had selected a simple random sample, the estimate of sampling error for our finding that 66% of our sample schools offer physics every year would be given by

$$S = \left(\frac{0.66(1-0.66)}{3472}\right)^{1/2}.$$

The confidence interval for this estimate is given by $\pm Zs$, where Z is the confidence coefficient. At the 95% confidence level used in this study, $Z = 1.96$ and the confidence interval for the finding that 66% of the schools offer physics every year would be $\pm 1.6\%$. In other words, if we drew repeated samples of schools and posed the same question to the principals each time, we would expect that 95% of the time we would come up with a proportion offering physics every year that fell within the range of 66% $\pm$ 1.6%, or 64.4% to 67.6%.

The stratified sampling procedure used here yields error estimates that will vary slightly from those generated by a simple random sampling and described by the above formula. Stratification prior to sampling by itself generally reduces sampling error somewhat, while disproportionate sampling of strata tends to heighten it, relative to a proportional sample of the same size (varying, of course, with the degree of disproportionality). Overall, the extent of the differences for the procedure employed here are likely to be quite small. The same holds true for findings involving medians, where the formula appropriate to simple random samples at the 95% confidence level yields an interval of

$$\pm 1.96\left(\frac{0.25}{n}\right)^{1/2}$$

as well as for findings involving means, where the corresponding interval is defined by $\pm 1.96s/(n)^{1/2}$, where s is the standard deviation of the distribution. (The finite population correction factor will be negligible due to the relatively large sample and low sampling rate, and has been omitted from the calculations above.) Finally, it should be noted that differences in means, medians, and proportions were generally made the focus of discussion in the body of the report only when they were substantial as well as merely statistically significant.

The level of sampling error present in our estimates for findings derived from teachers' responses is likely to be further compounded by the clustered sampling approach we employed, in which we sampled schools and then took a census of physics teachers at those schools. The increased error, relative to the levels likely if we had been able to sample from a pre-existing list of all physics teachers across the country, derives from the potential effect of a higher degree of homogeneity for many of our key variables among respondents at multi-teacher schools. Since the vast bulk of respondents were the only physics teacher at their school, the overall impact of the heightened homogeneity of responses is likely to be small, but where we focus on multi-teacher schools, the impact may be somewhat greater. In addition, there is higher risk of contamination at these schools, where teachers had more opportunity to discuss the survey and their responses to specific questions with colleagues.

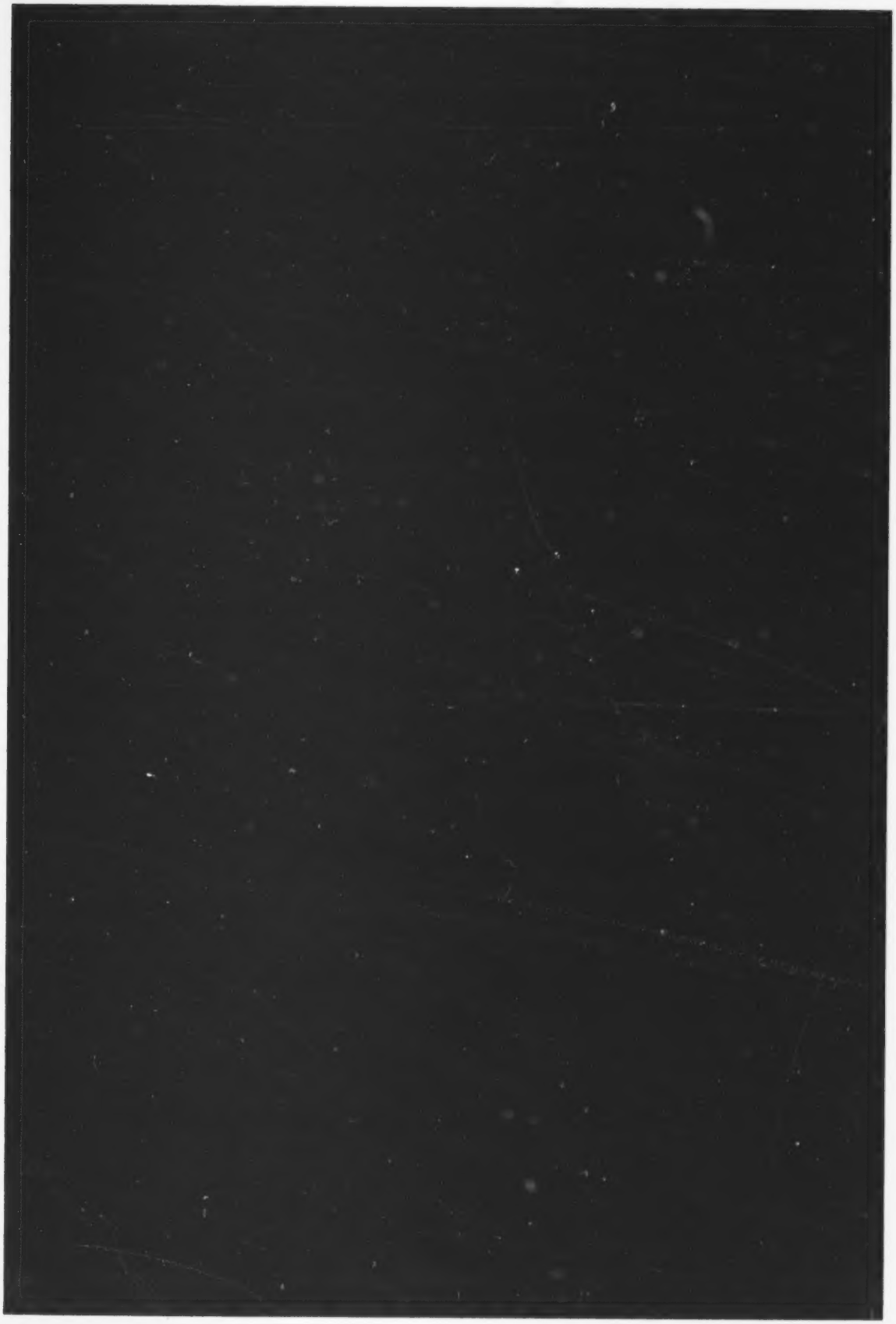
In addition to error arising from the design of the sampling procedure, our findings may reflect a bias resulting from systematic differences between the teachers who responded to the survey and those who didn't. Needless to say, response bias does not figure in as a problem for estimates regarding the population of schools that are derived from variables taken from the original QED data base. Similary, the almost 100% response from principals rules out the possibility of meaningful response bias for our estimate of the number of schools offering physics annually or in alternate years, or the proportion of students attending the schools in these categories. But the presence of such sources of data for all schools in the sample gives us a convenient way of examining some of the attributes of the schools which contained teachers who did not respond to the survey, and comparing these to the characteristics of the schools employing those teachers who did respond. This is done to try to get some idea as to whether systematic differences between the two groups make our findings which are derived from items in the questionnaire (and thus solely dependent on teachers who responded) less representative of the teacher sample as a whole. Thus Table A-3 presents comparisons of the schools at which respondent and non-respondents taught.

In general, the differences evidenced in the table are either not statistically significant, or are significant but slight. Among the variables which showed no significant difference were the urban, suburban or rural setting of the school, the number of teachers having physics classes in the Spring of 1987, or the frequency with which physics is offered at the school. On the other hand, non-respondents were slightly more likely than respondents to come from private schools, from schools in states located in the Middle Atlantic, Southern Atlantic, or East South Central regions of the country, and from schools which combined primary and secondary grade levels. Finally, while respondents from schools in different size categories showed slight differences in response rate, these differences were not systematic by size. Overall, there was no statistically significant difference in the average number of students per grade for respondents' and non-respondents' schools.

Data on most of the variables with which we were concerned were, of course, not available on the QED database—hence the need for the survey. By the same token, however, data on these variables is not available for non-respondents, and

thus we have no way short of conducting a separate survey of non-respondents, of ascertaining the extent to which response bias skews our findings involving these attributes. One method often used to provide a rough estimate of the possible presence of such response bias is to compare the characteristics of early and late responders, using the latter group as a surrogate for non-respondents in the sample. Such an approach has obvious imperfections, in that there may be systematic differences (or, for that matter, similarities) between those who ultimately respond and those who don't which are not present in comparisons of early and late respondents. Nevertheless, such a technique is often employed as a supplement to the type of direct comparisons which we have made in Table A-3 above. (See, for example, the National Research Council's 1981 Profile of Science, Engineering and Humanities Doctorates in the United States, Appendix G.)

In the case of our own survey, we divided respondents into those who responded to the first wave mailing, those who responded after postcard reminders were mailed out some five weeks later, those who responded to the second mail wave, sent out three weeks after the reminder, and those who only returned their questionnaire after follow-up telephone calls were made starting about three weeks after the second wave was mailed out. Comparisons of these four groupings of respondents are presented in Table A-4.



As evidenced in the table, with only one exception, no statistically significant differences were found between early and late responders. That one exception was highest degree earned, with early respondents being slightly more likely than late respondents to have earned a graduate degree. All in all, the results in Tables A-3 and A-4 suggest that the response bias for this study is slight, implying that the 75% of the teachers in our sample who did complete and return the questionnaire are substantially, though certainly not entirely, representative of the entire sample of 3301 teachers with physics classes.

It should also be recognized that other sources of error are likely to be present in the survey, and that these may well be as great or greater than either response bias or sampling error. Such sources include:

a) inacuracies and incompleteness in the original population listing of schools obtained from QED;

b) inaccuracies in the listing of current physics teachers provided by principals;

c) response errors arising from poorly worded questionnaire items, poorly-constructed or unduly complex items, or items requiring extensive recall of past experiences;

d) errors in coding or mistakes in interpreting responses to open-ended questions; and

e) mistakes in data entry and in computation.

Every effort was made to double check answers against other items and against external sources of data wherever discrepancies arose. For example, the listings of physics teachers by principals were compared to responses by teachers to an item asking for the number of other physics teachers at their school. Responses that differed from the answer given by the principal of that school were double-checked by telephone. Nevertheless, error from all these sources is undoubtedly present in the data from which the findings were derived. In most instances, the accuracy of answers were impossible to cross-check. (For example, while the vast bulk of teachers filled out and returned their questionnaires during the Spring term of 1987, about 10% waited until after the summer recess to return theirs. Some of the responses—for instance, items on problems encountered or objectives pursued in teaching—may be especially sensitive to the pressures of work, and may look different from the vantage point of summer than they do during the school year.) Error from sources such as this cannot be determined with accuracy, and this requires that all findings be interpreted with caution. Replication in follow-up studies will help to permit a better gauging of the accuracy and reliability of the initial findings reported here.

REFERENCES

(1) Fiske, Edward B. "Searching for the Key to Science Literacy" *New York Times Education Supplement*, 1/4/87, 20.

(2) Walsh, John "Breakthrough for Education at NSF?" *Science* **240**, 272.

(3) Aldridge, Bill G. *Survey Analysis of U.S. Public and Private High Schools: 1985–86*, National Science Teachers Association, Washington, D.C., Appendix I.

(4) National Center for Education Statistics, U.S. Department of Education, *High School & Beyond Transcript Study* (1980 panel), cited in Czujko, Roman and David Bernstein (forthcoming), *Secondary School Science and Mathematics Education*, American Institute of Physics, New York.

(5) Education Commission for the States, *National Assessment of Education Progress* (1976–77) and *Science Assessment and Research Project* (1981–82), cited in Welch, W. W., L. J. Harris and R. E. Anderson (1984) "How Many Are Enrolled in Science?" *The Science Teacher* **51** (9), 14–19.

BIBLIOGRAPHY

Aldridge, Bill G. (1986) *Survey Analysis of U.S. Public and Private High Schools: 1985–86*, National Science Teachers Association, Washington, D.C.

American Institute of Physics (1960) *Physics in Your High School*, American Institute of Physics, New York.

American Institute of Physics (1964) *Physics—Education, Employment, Financial Support: A Statistical Handbook*, American Institute of Physics, New York.

Czujko, Roman and David Bernstein (forthcoming) *Secondary School Science and Mathematics Education*, American Institute of Physics, New York.

Ellis, S. (1987) *1985–86 Graduate Student Survey*, American Institute of Physics, New York.

Ellis, S. (1988) *1986–87 Survey of Physics and Astronomy Bachelor's Degree Recipients*, American Institute of Physics, New York.

Evangelauf, Jean (1987) "School-Reform Drive Spotlights Colleges' Education of Teachers" *The Chronicle of Higher Education*, 9/27/88, A48.

Fiske, Edward B. "Searching for the Key to Science Literacy" *New York Times Education Supplement*, 1/4/87, 20–23.

Franz, Judy R., Bill G. Aldridge and Robert Beck Clark "Paths to a Solution" *Physics Today* **36** (9), 44–49.

Holton, Gerard (1986) *The Advancement of Science, and Its Burdens*, Cambridge University Press, Cambridge, England.

International Association for the Evaluation of Educational Achievement (IEA) (1988) *Science Achievement in Seventeen Countries: A Preliminary Report*, Pergamon Press, Oxford, England.

Kearns, David T. and Denis P. Doyle (1987) *Winning the Brain Race: A Bold Plan to Make Our Schools Competitive*, Institute for Contemporary Studies, San Francisco.

Klein, Margrete S. and James Rutherford (1985) *Science Education in Global Perspective: Lessons from Five Countries*, American Association for the Advancement of Science, Washington, D.C.

Koretz, Daniel M. (1987) *Educational Achievement: Explanations and Implications of Recent Trends*, Congressional Budget Office, Washington, D.C.

Layman, John W. (1983) "The Crisis in High-School Physics Education: Overview of the Problem" *Physics Today* **36** (9), 26–30.

Oleck, Joan "Gathering the Gifted Under One Roof" *New York Times Education Supplement*, 1/4/87, 24–25.

Pfeiffenberger, Will and Gerald F. Wheeler (1984) "A Curriculum Survey of High School Physics Courses, *The Physics Teacher*, 12/84, 569–575.

Porter, Beverly Fearn and William H. Kelly (1983) "Why Physicists Leave Teaching" *Physics Today* **36** (9), 32–37.

Rothman, Robert (1987) "NSF Urged to Boost K–12 Effort" *The Scientist*, 10/5/87, 7.

Shamos, Morris H. (1988) "A False Alarm in Science Education" *Issues in Science and Technology* **IV** (3), 65–69.

Skelton, W. Keith, Roman Czujko, and Dawn Kellman (1987) *1985 Salaries: Society Membership Survey*, American Institute of Physics, New York.

Walsh, John (1988) "U.S. Science Students Near Foot of Class" *Science* **239**, (4585), 1237.

Weiss, Iris (1978) *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*, Center for Educational Research, Research Triangle Park, NC.

Weiss, Iris (1987) *Report of the 1985–86 National Survey of Science and Mathematics Education*, Research Triangle Institute, Research Triangle Park, NC.

Welch, W. W., L. J. Harris and R. E. Anderson (1984) "How Many Are Enrolled in Science?" *The Science Teacher* **51** (9), 14–19.

Wilson, J.M. and Tim C. Ingoldsby (1983) "Places Where Things are Right" *Physics Today* **36** (9), 52–60.